

SCIENTIFIC RESULTS OF THE
SNELLIUS EXPEDITION

IN

THE EASTERN PART OF THE
NETHERLANDS EAST-INDIES
1929-1930

VOL. I - CHAPTERS I-IV

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN
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VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË
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ONDER COMMANDO VAN

F. PINKE

LUITENANT TER ZEE DER 1^e KLASSE

1929—1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET
NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN
HET KONINKLIJK NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP



GEDRUKT DOOR EN TE VERKRIJGEN BIJ

E. J. BRILL — LEIDEN



Thompson

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE



VOL. I

VOYAGE

CHAPTER I

PROGRAMME OF RESEARCH AND PREPARATIONS

BY

P. M. VAN RIEL
(LEADER OF THE EXPEDITION)

1937

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CHAPTER I

The first part of the book is devoted to a general survey of the history of the subject. It begins with a brief account of the early attempts to explain the origin of life, and then proceeds to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The second part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The third part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The fourth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The fifth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The sixth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The seventh part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The eighth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The ninth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions. The tenth part of the book is devoted to a more detailed consideration of the various theories which have been advanced. The author then discusses the evidence in support of each theory, and finally arrives at his own conclusions.

FOREWORD

Owing to a variety of circumstances, our first volume dealing with the scientific results of the Snellius-expedition is only now able to appear, after several others (Vols III and VI as well as portions of II and V) which according to the original plan should have followed after it, have already been published. We are now able, however, to declare with all the more confidence that the expedition has been a success, confirming the expectations which were raised by the reports brought out during the voyage.

The idea of sending out an oceanographic expedition to the waters of the Netherlands Indian Archipelago was instigated by the realization that new instruments — especially the echo-sounding apparatus — and the improvement of those already in use combined with new ideas on research, had brought the practice of oceanography to a new phase. Moreover the deep basins in the Archipelago presented problems the solution of which was vital to more than one branch of science, not only to oceanography but to geology and geophysics as well.

While in the Siboga-expedition of 1900, biology stood in the foreground, physical oceanography came only in the second place and geology was not included in the programme at all, in the Snellius-expedition the parts were reversed and moreover a prominent place was given to geology. Thus the one expedition formed a complement to the other and the combined results were enriched by the gravitation researches made by Prof. Dr. F. A. Vening Meinesz in Netherlands submarines among the Archipelago, between 1923 and 1930 as well by some other local and isolated researches. As the Archipelago has been practically completely charted by the surveying vessels of the Royal Netherlands Navy assisted by the Indian Government ships, it may be said that the whole field of thalassography for this portion of the globe has been investigated. The area extending over more than three million square kilometres still offers opportunities for further research.

„The Maatschappij ter bevordering van het natuurkundig onderzoek der Ned. Koloniën” (Society for scientific research in the Netherlands colonies) and the „Kon. Ned. Aardrijkskundig Genootschap” (Royal Netherlands Geographical Society) together took the initiative in 1925 for organizing the expedition and set up an oceanographic committee, to whom they confided the preparations and to which later the leader chosen, the commander of the ship and the members of the staff were added.

Financially the expedition was made possible by the generous support lent by the Netherlands Indian Government, both in money and material, backed by the Home Government. Moreover important financial contributions were sent from many quarters, headed by members of the Royal Family.

This liberal and manifold support not only enabled the expedition to be undertaken but also provided means for the working out of the observations made and the material collected, and for the publications of the results obtained.

The success of the expedition is due, in the first place to the leader, P. M. van Riel then director of the department of Oceanography and Maritime Meteorology of the Royal Netherlands Meteorological Institute, the captain of H.M.S. „Willebrord Snellius”, Lieutenant-Commander F. Pinke and with them the members of the scientific staff Prof. Dr. H. Boschma, Dr. Ph. H. Kuenen, Dr. A. Boelman, Dr. H. C. Hamaker and Dr. H. J. Hardon. Furthermore the officers, of whom the senior officer, J. P. H. Perks should be mentioned, not forgetting the warrant and petty officers and all the other members of the crew.

Besides all these, many persons have given their help and support in the preparation and

execution of the work and the elaboration of the data collected, too numerous to be all mentioned by name. One exception, however, must be made in the case of the late Prof. Dr. Max Weber, the leader of the Siboga-expedition. From the first he took a cordial interest in the new expedition and contributed to its success, also, as member of the oceanographic committee.

The Snellius-expedition has played its part in the many-sided scientific study by Netherlanders of those beautiful and interesting islands lying on the equator, which form a part of the Kingdom of the Netherlands. May it never be forgotten by our people that in the field of pure science too they have an ever-present mission to fulfil towards Insulinde.

The Hague, September 1937.

The President of the
Oceanographic Committee
D. FOCK

The Secretary
J. L. H. LUYMES.

CHAPTER I

PROGRAMME OF RESEARCH AND PREPARATIONS

A. THE AREA OF RESEARCH

From the peninsular of Malacca and the coast of Cochin China a huge continental shelf (THE SOENDA SHELF) extends south-east, which is now covered by the South China and the Java seas with a depth of less than 100 metres. The depth contour of 100 metres runs past the islands of Sumatra, Borneo and Java connecting them to the Asiatic continent.

We find a similar connection in the eastern part of the Indian Archipelago, where the bottom of the Arafoera sea (THE SAHOEL SHELF) connects the Aroe islands and New Guinea with Australia.

In the intervening area, however, the contour of the sea floor is of a totally different character, instead of the shallow seas on the west and the east, we here find partially enclosed seas of very great depth and with steep coast-lines.

Of these inland seas we mention: the Banda sea, with a depth of over 7400 metres in the eastern part (*the Weber deep*), the Celebes sea with its level bottom more than 6200 metres below the sea level, the Sulu sea where the greatest depth is a good 5500 metres and the Flores sea with a maximum depth of more than 5100 metres.

This deep sea area is to some extent comparable with the Mediterranean sea and the Caribbean sea with the Gulf of Mexico. Also between Europe and Africa and between North and South America we find seas enclosed to a certain depth, but not to such an extent as in the Indian Archipelago. While the first two mediterranean seas are only open to the ocean on one side, the Austral-Asian basins lie between two huge oceans, the waters of which exercise an influence upon the conditions of life in these enclosed waters down to very great depths.

These deep basins are divided from each other and from the adjacent oceans by comparatively shallow sills, across which the renewal of the deep water within must take place. The renewal may come from the neighbouring ocean or even when the area in question is in direct connection with the open sea it may be drawn from the adjacent basin ¹⁾. From which of these sources the renewing bottom water will come depends entirely upon where the heaviest water can enter, because only water with the highest specific gravity can replace the deep water. In most cases it will come through the deepest entrance.

The depth of the entrances to the different basins varies from 400 metres to 3130 metres. Consequently the physical and chemical properties of the water in these basins below the sill level will vary considerably.

This alone would make the determination of these properties of importance to biologists, and moreover an investigation would be able to show in how far the temperature of water in the inland seas below a certain depth is raised by the higher pressure under which water flowing from the sill into the depth comes to lie. An oceanographic examination of the deep-sea area will thus yield not only a further insight into the influence exercised by the two oceans upon the water of the inland seas, but owing to the peculiar situation of this area, the results will be of importance to the whole science of physical oceanography.

¹⁾ This is the case in the Sawoe sea for instance.

The East Indian Archipelago is moreover a field of great interest to the geologist. The two shelves, east and west, are considered to be geologically stable; but in the intermediate area, on the other hand, the earth's crust is in a state of disturbance and the subterranean forces are constantly giving rise to new formations. The question of whether the tectonic and the volcanic phenomena are caused by contraction of the earth, by horizontal movements of the continents or by other transformations at great depths, are problems with which many geologists are occupied.

To find the solution of these problems, the first essential is that examination of the earth's crust shall not be confined to the visible portion only. An ample supply of data concerning the state and shape of the sea floor in the inland seas, where the contours are so highly irregular, are obviously of the utmost importance. Moreover the great length of the coast-line, diversity of the coast formation and numerous and variegated coral reefs offer ample opportunities for studying the disturbances of the earth's crust and the variations of the sea level. Finally, the area being rich in volcanoes it presents especial facilities for volcanologic research.

The rich field for biologic research that this area offers has already been demonstrated by the Siboga-expedition and the results which it produced (4)¹⁾. We have referred above to the peculiar conditions existing in the enclosed seas in water layers lying deeper than the sills, which differentiate them from the open ocean and are of especial interest. For the chemist the determination of these peculiar conditions are also of the utmost interest.

G. Schott (1) says with regard to this area „Eine sicher überaus lohnende Aufgabe für die „Niederländische Wissenschaft wäre es ein ganz neuzeitliche ozeanographische Untersuchung „jener Gewässer vorzunehmen, die schon dank der Gunst der klimatischen Verhältnisse dem Erfolg „nicht neidisch wehren, wie es bei unwirtlichen Meeresgegenden leicht der Fall ist. Probleme „mit ganz fest umrissenem Inhalt bieten sich von allen Seiten“.

The ship being equipped essentially for deep-sea research, only a few observations will be made on the continental shelves. The field of research will therefore embrace the basins and troughs lying to the east of Borneo. But so as to be able to compare the results with those in the adjacent oceans, the qualities of the sea water in the North Pacific and the neighbouring area of the Indian Ocean will be determined. It would crowd the programme to extend the research to the areas south of Java and south-west of Sumatra. At the same time the peculiar position taken by the deep Sulu sea with its shallow entrances make it desirable to include it as far as is possible in the investigations.

The field is thus limited by parallels Lat. 10° N. and Lat. 12° S. and by the meridians Long. 112° and 135° E. The sea area lying between these limits covers about three million square kilometres. Some idea of the magnitude of the area investigated is given by Plate I where a portion of the East Indian Archipelago is imposed upon the map of Europe.

B. PREVIOUS INVESTIGATIONS (Pl. II)

The above particulars will have made it clear that an intensive examination of the deep inland seas is of exceptional interest from a biological, geological and oceanographic point of view. In the field of oceanography especially, our knowledge was quite inadequate to the importance of the area.

In the field of biology the most important material was collected by the Siboga-expedition in 1899—1900, under the leadership of Prof. Dr. M. Weber. This material has provided the subject for a great number of monographs and has not yet been exhausted. (4).

The results already obtained concerning the distribution of the bottom animals proved to be so extensive that it was not considered necessary to repeat or continue this research, especially as the „Siboga“ cruised almost the same area as was chosen for the Snellius-expedition. Other expeditions have examined more confined areas, such as North Celebes, Ambon, Aroe islands and Kai islands.

So far little was known of the nature of the reef formations. A great number of corals were collected by the Siboga-expedition; but much was still to be learned about the distribution of corals. It was not known in how far the vertical distribution of plankton in the more or less closed basins

¹⁾ The numbers between brackets refer to Bibliography, p. 37.

of the area to be examined differs from that in the ocean. With regard to the horizontal distribution it was not known to what extent the plankton in the central portions of the vast inland seas was of an oceanographic nature or whether it was mixed with neritic forms.

The investigations carried out by geologists in the area in question were very numerous. These were primarily confined to the collection of data on land, but important contributions had also been made from the examination of coral islands and reefs and from bottom samples brought up from various depths.

But the number of soundings was not yet sufficient for determining the submarine contours, while the examination of the sediments was confined to the surface of the sea floor. As no long bottom samples bored out of the bottom were available it was not possible to investigate the construction of the firm sea floor in deeper layers and to ascertain if it was a stratified formation. No expedition had so far carried a geologist on board.

This is not the place, neither is the writer competent to give a detailed account of the biological and geological results attained previous to our expedition, but we may refer to what Mrs. Weber-Van Bosse, M. Weber and G. A. F. Molengraaff have written in „De Zeeën van Nederlandsch Oost-Indië” (6); more on this subject will be found in the extensive bibliography, added to these papers.

In the field of physical-chemical oceanographic research, previous to our expedition, we may review the following branches, arranged according to the extent of our knowledge of the subject.

- a. The surface of the sea.
- b. The depth, bottom temperature and composition of the sea floor.
- c. The temperature and chemical properties of the sea water between the bottom and the surface.
- d. The circulation of the water between the bottom and the surface.

a. THE SURFACE OF THE SEA.

Research in this field has been principally directed to currents and temperature. Accurate data as to the salinity of the surface water were published by K.M. van Weel. (21).

b. DEPTH, TEMPERATURE AND COMPOSITION OF THE BOTTOM.

Numerous depth determinations were made by the surveying vessels of the Royal Dutch Navy, within a depth-line of 200 metres. Furthermore several wire soundings were made outside this area, but there was far from sufficient data to ascertain the contours of the deep sea.

The number of observations of bottom temperature and composition of the deep sea floor were even less, as the wire soundings were not regularly accompanied by determination of temperature near the bottom, or by collecting bottom samples.

c. TEMPERATURE AND CHEMICAL PROPERTIES OF THE SEA WATER BETWEEN THE BOTTOM AND THE SURFACE.

Research in this field was confined to the eastern part of the Archipelago and to a few expedition ships. We need not take into account anything previous to 1874, when one of the most important expeditions was sent out by the English Government in the „Challenger” (2). This vessel investigated the area of research in 1874—1875 and was speedily followed by the German ship „Gazelle” (3). Both vessels determined temperature and density of the water at some stations in the Banda sea, Celebes sea, Molukken sea and Sulu sea at various depths, while the gas contents of some samples were determined; on the „Gazelle” chemical investigations were extended to some other properties of the water.

The „Siboga” (1899—1900) (4) also carried out temperature determinations at various levels. During this expedition the emphasis was, however, laid upon the biological elements, and owing to the impossibility of replacing lost instruments quickly enough, the activities in physical-oceanographic direction had to be curtailed.

The researches of these expeditions undoubtedly yielded important physical-oceanographic

results, although the number of stations was limited, and the accuracy of the methods employed and the instruments used was not up to the present standards.

On the German research vessel „Planet” (5) in 1906, for the first time more modern and reliable instruments were used. This vessel, however, remained only a short time in the area of the deep inland seas, while the research was chiefly directed to the determination of temperature and salinity by Cl-titration of the surface water.

d. CIRCULATION OF THE WATER BETWEEN THE BOTTOM AND THE SURFACE.

Very little was known with certainty of the horizontal and vertical motion of the water beneath the surface of the seas. It is true that Tydeman (6 b) had concluded from the absence of soft bottom deposits at the entrances of the basins that there was a strong sill current for the renewing of depth water. But it was desirable to have more proofs, if possible by direct measurements, of what Tydeman assumed as a certainty.

The above gives a brief summary of the principal oceanographic researches of the last 60 years in the *deep seas* of the eastern Archipelago and the adjacent parts of the Pacific and Indian Oceans. A full account of all researches is given in „de Zeeën van Nederlandsch Oost-Indië” by S.P. l'Honoré Naber (6a) in his „Historical review”. More particulars concerning the temperature are published by G. F. Tydeman (6b). W. E. Ringer (6c) treats of the temperature and the chemical properties of the sea water. Tables containing all observations carried out in the area 20° N. — 30° S. and 70°—150° E. by „Challenger” (2), „Gazelle” (3), „Vitiaz” (7), „Valdivia” (8) and „Planet” (5), are added to this chapter.

As to the shallow seas we must mention the accurate temperature and salinity observations, made between surface and sea bottom in the Java sea, Southern China sea and Malacca strait by K. M. van Weel (9). H. P. Berlage (10) discusses the results of these observations in relation to the monsoon-currents in the Java sea. As far as concerns mean values for surface temperature and current we refer to J. P. van der Stok (6d), H. P. Berlage (22), the publications of the Royal Netherlands Meteorological Office at de Bilt (23) and the Pilots for the Netherlands East-Indies. (24).

The chemical properties of the sea water still left a large field for research open. The temperature observations carried out in the deep-sea with minimum thermometers and readings to a 10th of a degree Celsius, were yet not sufficiently accurate to register minute changes with depth. It is just these minute changes in temperature and salinity — to mention only the most important properties — which in layers lower than the deepest sills may give the clue to the circulation of the water in the inland sea, and its renewal.

A systematic research into the physical and chemical properties of the sea water was therefore highly desirable. For this purpose it would be necessary to take observations between the surface and the bottom at a large number of stations, using reliable instruments and working according to modern methods.

C. DEVELOPMENT OF PLAN OF THE EXPEDITION

We have pointed out above, that the oceanographic knowledge of the inland seas of the Indian Archipelago was very limited. In connection with this Captain J. L. H. Luymes, Hydrographer of the Navy, addressed a note on the subject to the „Maatschappij ter bevordering van het natuurkundig onderzoek der Nederlandsche Koloniën” (Society for scientific research in the Netherlands Colonies) which induced this Institution, together with the „Koninklijk Nederlandsch Aardrijkskundig Genootschap” (Royal Netherlands Geographical Society) at Amsterdam to form a committee whose task it was to prepare an extensive scientific research in the Archipelago.

The members of this Committee were: Dr. J. C. Koningsberger, president; Dr. W. van Bemelen; Prof. Dr. B. G. Escher; Prof. Dr. E. van Everdingen; C. J. de Goeje; Captain J. L. H. Luymes; Prof. Dr. G. A. F. Molengraaff; Prof. Dr. W. E. Ringer; Vice-Admiral G. F. Tydeman; Prof. Dr. Max. Weber, leader of the Siboga-expedition, and K. M. van Weel, secretary. On his appointment as Colonial Secretary the president resigned his post and was temporarily substituted at first by Prof. Dr. M. Weber and after him by Prof. Dr. G. A. F. Molengraaff; subsequently the latter's

place was taken by the ex-Governor General of the Netherlands East-Indies Dr. D. Fock. After Mr. van Weel had resigned as a member, Captain Luymes was appointed secretary.

The first meeting was held on Sept. 24th 1925. In discussing the various desiderata it proved that the Committee was unanimous in considering that besides the oceanographic research geological and biological investigations should be carried out.

The Committee's point of view was that the expedition should envisage more objects than those undertaken 25 years ago by the „Siboga". At that time the principal purpose besides the collection of deep-sea soundings and bottom samples was research in the fields of botany and zoology. Now, beside the further extension of our knowledge of the contours and composition of the sea floor, the principal aim was the collection of oceanographic data as regards the physical and chemical properties of the sea water, furnishing a more comprehensive idea of the conditions of life and the movement of the waters between the surface and the sea floor. Moreover, the latter would be determined by means of direct observations (current measurements).

For the geological research, the Committee considered it to be of great importance to take long bottom samples, as well as a large number of depth determinations. The programme must also include investigations of the symmetry of ridges and troughs, the positive and negative shifting of the coast-line and recent volcanic activity.

The chief object of the biological research would be collecting plankton, and the examination of organisms on coral reefs and on the sea shore.

For the meteorological research it was considered desirable to keep the official meteorological log for at least six observations per diem, with some additional observations concerning other meteorological elements.

The Committee had hopes that the Government of Netherlands India would be willing to place one of the surveying ships with her crew at their disposal. Being of opinion that the projected research would do no more than open up this very large field of investigation it was considered that a period of 15 months would be sufficient for what they had in view. Finally the Committee had to consider the selection of the scientific staff and other members of the expedition.

D. APPOINTMENT OF THE MEMBERS OF THE EXPEDITION AND THEIR ASSISTANTS

As leader of the expedition and oceanographer, the retired Naval Lieutenant first class P. M. van Riel, Chief of the oceanographic and maritime-meteorological section of the Royal Netherlands Meteorological Office at de Bilt was appointed; as biologist Prof. Dr. H. Boschma; as geologist Dr. Ph. H. Kuenen; as chemist Dr. A. B. Boelman; as assistant to the leader Dr. H. C. Hamaker physicist and Dr. H. J. Hardon chemist, and as assistant for chemical determinations and administrative duties Mrs. M. M. H. van Riel-Verloop.

Although naturally the personnel of the Royal Navy would have a great share in the work of the expedition, no definite naval appointments could be made until a complete programme of work had been fixed and the financial basis settled. The Committee considered it of great importance that a skilled mechanic should be included in the staff for the care and when necessary the repair of instruments and apparatus. The success of an expedition and the reliability of its observations naturally depend much upon the state of its instruments. One of the Navy's mechanics would therefore be of great service to the undertaking.

The prospective leader was invited by the Committee to draw up a programme of the oceanographic work to be undertaken, and what instruments and what equipment of the ship would be needed, as well as a plan of the whole expedition and an estimate of the costs. A similar invitation confined to their own subject, was sent to the biologist, the geologist and the chemist. All these had to be within the scope of the principles laid down by the Committee.

A certain sum was laid down for travelling and verbal consultation with foreign colleagues. The information obtained in this way and the experience gained by previous expeditions contributed materially to the success of the work. The author refers here especially to the physical-chemical oceanographic research and the great help given by Norwegian and German experts in the preparation of the expedition. We shall return to this later.

E. FURTHER ELABORATIONS OF THE PLANS

Assuming the duration of the expedition to be 15 months, the following programme was worked out in consultation with the Snellius Committee, so called after H. M. S. „Willebrord Snellius" (in course of building) had been placed at the disposal of the expedition by the Indian Government.

1. PHYS. CHEM. OCEANOGRAPHIC RESEARCH.

- a. Echo-soundings and wire soundings, the latter accompanied by determination of bottom temperature, chemical properties of the sea water near the bottom and the collection of bottom samples.
 - b. Determination of surface temperature by constant registration and direct measurement, observation of currents at the surface during the voyage and collection of surface samples for the determination of their chemical properties.
 - c. Serial observations between the surface and the bottom at a great number of niveaux for the determination of temperature and chemical properties of the water at some 200 stations.
 - d. Registration of current in various depths at anchor stations in the inland seas and dividing sills.
 - e. Observations of the colour and transparency of the sea water.
It was expected that these observations would throw light upon:
 1. The form and construction of the sea floor.
 2. The circulation of water between surface and bottom in the inland seas and the exchange of water between the basins themselves and between them and the adjacent oceans.
 3. The increase of temperature with depth in the partially enclosed basins below a certain niveau.
 4. The stability of the various water layers.
 5. The occurrence of periodic variations of short duration in the properties of the sea water at various niveaux.
- The expedition was considered to be too short for the determination of seasonal variations or changes from year to year, though some insight in the seasonal variations has been acquired during the expedition.
6. The conditions of life between the surface and the bottom by determinations of the salinity, the oxygen content, the P_H -concentration, the alcalinity and the content of certain nutritious salts at various depths.

2. GEOLOGICAL RESEARCH.

The important increase in the number of depth determinations which can be expected from the use of an echo-sounding installation, will be of the utmost value in determining the contours of the sea floor in this geologically active area. New light will be thrown upon various geological problems, in connection with the crust of the earth and the deformation that takes place in it.

By a numerous collection of bottom samples the distribution of the sediments which are now forming will be better known. A simultaneous collecting of plankton and the determination of the circulation and properties of the sea water will throw light upon the cause of the distribution and the presence of certain qualities in the bottom deposits. One of the most interesting problems in this connection is the de-calcification of the sediments in the enclosed basins at great depths, which is here greater than in the open ocean.

An effort will be made to procure the longest possible bottom samples, so as to be able to see what deposits were laid down in earlier periods.

In collaboration with the biologist the formation of coral reefs will be studied. Data as to the changes of level of the earth's crust and the surface of the sea will be collected by an examination of the raised reefs. It may be possible to distinguish between these two and an estimation of the rate of such movements may be practicable.

As there are many islands (both volcanic and non-volcanic) which are little explored geologically or not at all, the necessary attention will be devoted to these.

3. BIOLOGICAL RESEARCH.

A collection of plankton at the various stations and the tracks lying between them, will furnish a scheme of the horizontal and vertical distribution of the organisms.

With regard to the horizontal distribution the collection must be made in such a way that the areas of pure oceanic plankton can later be distinguished from those where it is mixed with neritic plankton.

Special attention will be given to collecting different specimens of plankton in those places where the bottom sediment is of a peculiar character.

The plankton flora and fauna are of a different character at different depths. This vertical distribution has been well studied in the open oceans, but the more or less enclosed basins still offer a field of great interest. A comparative examination of the Sulu and the Celebes seas may lead to important results in connection with the various properties of the sea water at the same niveau.

The examination of coral reefs will be carried out on both old and recent formations which will be compared with one another, a further item on the programme being a minute investigation of a few atolls, to ascertain if they present marked differences in this area with the well known atolls in the Indian and Pacific Oceans.

In respects to the distribution of corals the expedition can make a valuable contribution by collecting corals accompanied by complete oecologic data. This will throw light upon the variability of coral colonies and the cause of their changes.

Finally research will be instituted in connection with the interesting fact that the Kai islands and the region to the north of them is one of the richest zoological areas of the earth, characterized by deep-sea animals being found at a much higher level than elsewhere.

4. METEOROLOGICAL RESEARCH.

The meteorological observations, taken during the voyage at different seasons can not be expected to provide sufficient material for a complete description of the normal meteorological conditions in the area of research. The object will be, primarily, to collect such data as are in direct or indirect connection with the oceanographic research.

This can be attained by keeping the usual meteorological log, in which particulars of wind, air pressure, air temperature, clouds, visibility and — of the surface of the sea — the water temperature, sea disturbance and surface current are entered.

These observations will be supplemented by observations of relative humidity, rainfall and intensity of the sun's rays. Few systematic observations on these points have hitherto been made in the area of research.

In the programme of geological research, submitted by Dr. Kuenen, the areas were shown where the collection of bottom samples was considered to be of most importance, and where an increase of our knowledge of the shape of the sea floor was most necessary. Moreover he pointed out the areas where the examination of coral reefs and islands promised to yield the most interesting geological results.

Prof. Dr. Boschma, in the biological programme, indicated the fields where most interest was expected from plankton research, the examination of coral reefs and of the litoral zone. In comparing the two programmes it appeared to me that the interests of the biologist and the geologist were identical with respect to the investigation of the shore and the coral reefs.

Taking both their wishes into account, and considering the demands of the physical-chemical-oceanographic research, the writer made a sketch of the route to be pursued, consisting of 13 separate tracks, by which the entire area could be cruised during the 15 months. This plan was based upon a preliminary schedule of research. (Plate III). In the construction of this plan I owe much to the help of Prof. Dr. G. Wüst of the „Institut für Meereskunde" in Berlin.

In settling the tracks over which our research was to be pursued, there were other things to be considered besides the strictly scientific objects of our cruise. They were:

a. *Supply and consumption of fuel*, in connection with the position of the places where supplies could be taken in.

b. The weather conditions in the area of research at different seasons. It was necessary to reckon with the climatological conditions in arranging the succession of the various tracks and the most favourable moment at which to begin, so as to render the observations as accurate and minute as possible and to avoid the chance of losing costly instruments which could not be easily replaced.

Valuable data concerning the meteorological conditions in the area of research were deduced from ships observations by J. P. van der Stok (11) while C. Braak (12) treats some sea areas in his work upon the „Climate of Netherlands Indies”, which deals principally with the land climate.

In the southern part of the area the summer and winter (northern hemisphere) are governed by the East and West monsoon respectively, with a transition period in March-April and October-November. In the East monsoon, especially, the wind in the Banda sea can be very strong, often accompanied by a troublesome swell and rough water.

In the northern part of the area, in the summer and winter (northern hemisphere) the South and North monsoon prevail respectively, while the spring transition lasts somewhat longer there. The month of May offers the most favourable conditions for the area south and east of Mindanao.

Typhoons and cyclones occur only in the most southerly and northerly part of the Archipelago, and then only rarely; at the same time it is necessary to reckon with the possibility of them in that area.

In the winter a strong west wind may blow in the Celebes sea (*Barat*). Generally speaking, it will be advisable to work in the north during the European summer and in the south in the winter. It is naturally during the transition period that calm weather conditions may be expected within the islands, so that for an expedition of 15 months it is advisable to start work at the beginning of this period.

If the weather conditions of the Archipelago have been well considered to begin with and the succession of the various tracks has been based upon them, a change in the date of commencement will be the more readily met by a change in the initial order of the cruises.

c. Rests. It will be advisable to make a break of about 6 days between each track (lasting about a month), for the control of apparatus and machinery, making up of delayed work, replenishing of provisions and fuel and to give a rest to the crew and members of the expedition.

d. Repairing of the ship. Twice during the expedition it will be necessary to make a longer stay at the Naval Docks at Soerabaia. The machinery is always in use, both while cruising and at the stations, while researches are carried out both by night and day so that there is not much time for repairs either to the ship or to the machinery. A longer stay at Soerabaia where the ship can be docked, is therefore essential.

After the Government had conditionally offered a suitable vessel with naval crew and exploitation costs, an estimate was drawn up for personal expenses, salaries, acquiring instruments and equipment of the expeditionary ship. Prof. Dr. B. Schulz of the „Deutsche Seewarte” at Hamburg was good enough to provide an estimate of the chemical equipment. The total cost of carrying out the above mentioned programme was estimated at f 200.000.

On the basis of the above particulars a complete plan was presented by the Snellius Committee to both the above mentioned Societies at Amsterdam.

The plans were approved by these bodies. The generous financial assistance that they offered and the no less important aid from the Indian Government, the contributions from industry, financial circles, shipping and commercial concerns and the many private contributions, headed by the Royal Family, together soon made up the required sum for the research. A special word of thanks is here due to the efforts of the financial committee.

Now the acquirement of instruments and the equipment of the ship could be begun, after the staff had consulted with some foreign colleagues on the subject.

The friendly relations existing between the Royal Netherlands Meteorological Office at de Bilt — and especially the Oceanographic Department — and the „Deutsche Seewarte” at Hamburg induced me first to consult their staff concerning the provisional plan for our expedition and the estimation of costs. The „Meteor” had not yet returned from its research in the Atlantic Ocean.

It is a pleasure to me to be able here to acknowledge much good advice and useful information received from the then president of the „Deutsche Seewarte“, the late Vice-Admiral Dominik and the two oceanographers Prof. Dr. Schott and Prof. Dr. Schulz.

The expedition owes much to the kindness of Prof. Dr. Helland Hansen and Prof. Sverdrup who during our visit of some weeks to Bergen in 1927 instructed Dr. Hamaker and myself in a variety of oceanographic subjects and moreover offered us an opportunity of participating in some oceanographic observations on board the „Armauer Hansen“ in the fjords and the open sea. The friendship and hospitality which these two oceanographers extended to us will always remain a grateful memory for us.

During my stay at Copenhagen, Prof. Dr. Martin Knudsen was so kind as to give me some valuable information and to demonstrate several modern oceanographic instruments in the Oceanographic Laboratory there.

The „Deutsche Wissenschaftliche Kommission für Meeresforschung“ at Hamburg was good enough to offer me an opportunity in 1927 of gaining some experience in the use of modern instruments and the application of modern methods during the research that was about to be undertaken by Prof. Schulz on the „Poseidon“ in the Barentz sea. As I was unfortunately unable to avail myself of the offer, Dr. Hamaker spent a fruitful fortnight on board the vessel in the Barentz sea. We are much indebted to Dr. Heinrici and Prof. Schott for their intermediary in this matter.

Returning from Stockholm in May 1927 from the meetings of the „Permanent International Council for the Exploration of the Sea“, I had the privilege of being present at the return of the „Meteor“ to Wilhelmshafen, and of becoming acquainted with those who had taken part in that important research in the Atlantic Ocean.

The return of the „Meteor“ at this moment was a very fortunate circumstance for the preparation and the arrangement of the Netherlands expedition. We were planning a similar oceanographic research, although on a somewhat more modest scale than that of the „Meteor“, and where could we receive better information than from the „Institut für Meereskunde“ in Berlin, where the German Atlantic Expedition had been prepared, and to which the majority of the returned oceanographic members of the staff were connected. I cannot express enough gratitude for the way in which the latter provided me with information as to the acquisition of instruments, the equipment of the ship and methods of observation. They gave me the full benefit of the experience gained by their successful expedition, so well prepared and commenced by the late Prof. Dr. A. Merz and after his death so efficiently pursued by the Commander, now Rear Admiral, Dr. F. Spiesz. My particular thanks are due to the Director of the Institute, Prof. Dr. Defant and to Prof. Dr. Wüst, the first oceanographer of the expedition.

The naval authorities in Berlin were also most kindly helpful so that on a second visit to the „Meteor“ at Kiel I was able to obtain information on practical ways of mounting the oceanographic instruments on board. Moreover the „Marineamt“ in Berlin kindly supplied drawings and instructions concerning deep-sea anchoring, which later enabled us during the current observations to anchor in depths of about 5000 metres. At the centenary of the „Gesellschaft für Erdkunde zu Berlin“, I had the pleasure of reading a paper upon „Die geplante Niederländische Expedition“.

From the middle of June to the middle of July Dr. Hamaker was again the guest of Prof. Helland Hansen on the „Armauer Hansen“, for oceanographic research in the North Atlantic, where Prof. Ekman was also present. The experience gained on the Norwegian vessel contributed to make the observations on the „Snellius“ work smoothly and reduced the loss of instruments to a minimum.

At the beginning of July, Dr. Boelman, the chemist attached to the expedition, stayed for a few days at Hamburg, to visit the „Carnegie“. From 8th to 26th November he was in succession in Hamburg and München, to hold consultations with the „Deutsche Seewarte“ and the former chemist of the „Meteor“-expedition, upon methods of chemical-oceanographic research and the arrangement of the laboratory.

The geologist, Dr. Kuenen, paid a visit in July to his colleague, Dr. Pratje, from the „Meteor“ and on the way home visited some dealers in Berlin.

Prof. Boschma visited England from July 24th to Aug. 11th. In London he had a consultation with some of the scientific staff of the „Discovery“-expedition, about methods of collecting plankton

and he was shown the apparatus which had been used on that ship. At Plymouth he made a few trips with the steam launch belonging to the laboratory. He also visited Liverpool and the Isle of Man, for information.

On the light-ship „Haaks” current-meters were tested by the prospective leader.

In Vol. II, Part 1, Ch.I a list will be given showing the instruments used for carrying out the above sketched oceanographic programme. The selection of these formed a very important part of the preparations. Due consideration had to be given to the funds available and to the observations that were to be taken, the manner in which they were to be carried out and the time necessary for each observation. It was essential therefore to draw up a complete plan and work it out to the minutest details. If this is not done, unpleasant surprises may occur, especially when the area of research is far away. A few remarks on this subject may be of value to future investigators.

If, for instance, we wish to estimate the number of reversing thermometers needed, we must consider the maximum depth at which observations are to be taken, the number of different levels at which observations are to be made and the number of series into which these niveaus shall be divided. Supposing the maximum loss to be one series by breaking of the wire during the whole course of the expedition, an idea is given of the number of instruments we must have in reserve.

Further we must take account of the vertical distribution of temperature, to determine the number of different kinds of thermometer for each series of which the interval (the highest and the lowest temperatures to be measured) allows the use at certain depths only. Moreover the possibility must be considered of using the same instrument at a station in different series, without delaying work and increasing the risk of mistakes through confusing the water samples. At the same time we must take care that in rapidly succeeding deep stations no stagnation in the work is caused by lack of instruments.

A very necessary piece of preparatory work is the construction of correction-tables, formulars, registers, etc. ready for recording observations and their necessary corrections and for registering the final results; if this is not systematically done it may lead to terrible confusion. In doing so the course of work down to the minutest details must be kept in view.

Another necessity is to collect all observations that have previously been made in our area. The data concerning the physical-chemical properties of the sea water in the eastern part of the Archipelago already known, were entered on working charts, while the common charts of the area were filled in with the known soundings beyond the depth line of 200 metres, thanks to the kind assistance of the Hydrographic Department of the Ministry of Defence.

Lists were made of the apparatus and instruments purchased, with the dealer's price and address, while a code was established to facilitate the ordering of new instruments.

Mrs. van Riel and some of the naval personnel received instruction in the determination of oxygen and chlorine content of the sea water. A film apparatus was purchased and entrusted to the geologist of the expedition, Dr. Kuenen, who received instruction in the manipulation of the apparatus beforehand.

Some technical volumes dealing with the research were added to the library of the „Snellius” for reference. A word of sincere thanks is due to Mrs. Dr. Weber-van Bosse, who 30 years previously had accompanied the Siboga-expedition in the same area as botanist, for her valuable contribution to the library.

F. THE EXPEDITION SHIP ¹⁾

As there was no suitable vessel in Holland, the Snellius Committee turned to the Ministry of Defence with the request that, as in the case of the Siboga-expedition, they would lend one of the ships of the Royal Navy with crew for the expedition, in which the officers and crew would take an active part. As the cost of building and navigating a vessel of the required sort would far exceed the resources available by the Committee, the possibility of the expedition was entirely dependant upon the answer to this request. After consultation had been held with the authorities in the Indies,

¹⁾ In the following chapter commander Pinke gives a complete description of the Expedition Ship.

the Snellius Committee was assured that the Dutch Navy would lend the necessary assistance, in accordance with its ancient traditions.

Now the space on board a naval vessel is usually so arranged that after the proper crew has been shipped little room is left for a considerable staff of scientific workers as well. Moreover the work requires a draughting-room, laboratories and dark room, and space must be found for the accommodation of special oceanographic apparatus. On a surveying vessel the circumstances are more favourable and such vessels are more suited to our purpose in other respects as well. Therefore the government of Netherlands India put the surveying vessel „Eridanus” at the disposal of the expedition. This vessel, however, was lying in the East-Indies.

In working out the plans for the expedition and especially after consultations with my German colleagues it became more and more evident that the equipment of a ship with such an extensive programme from out Holland, would be accompanied by very serious difficulties, such as would even jeopardize the success of the whole undertaking. When it came to my knowledge that within a certain time an observation ship was going to be built in Holland and was destined for the East-Indies, it was my obvious duty to propose to the Snellius Committee that they should request the use of this vessel for our purpose, even if this should cause the expedition to be postponed for a year. If we acquired this vessel the difficulties of equipment would be overcome, but this would not be the only advantage. The new vessel would be provided with modern echo- and wire-sounding apparatus and a heavy machine for anchoring in very deep water (5000 to 6000 m.), during the building a chemical laboratory and cabins and laboratories for the geologist and biologist could be made, while the arrangement of these and the equipment of the ship could all take place under the eye of the experts concerned. Finally, not the least important was that by this means the scientific staff would be able to make the voyage out in the expedition ship and in company with the officers and appointed crew, become familiar with the activities of the expedition and the instruments to be made use of.

By conceding to this proposal, the Indian Government contributed greatly to the success of the undertaking. The new ship was laid down on Nov. 1st 1927 by the yard „Fyenoord” at Rotterdam. At the beginning of 1928 Lieutenant 1st class F. Pinke was appointed commander of the new ship and entrusted with the nautical-technical supervision. It gave me a feeling of great confidence to have beside me in the last year of complicated preparations, a man of such knowledge, insight and energy, in attacking all the problems bound to the installation of the apparatus and the equipment of the ship. The great support given by the commander and later by his officers and crew were of the utmost worth.

Dr. Hamaker was an invaluable assistant in selecting and purchasing apparatus, owing to his experience gained on foreign research vessels and his instinctive feeling for instruments. All instruments, which arrived successively at the Meteorological Institute at de Bilt, were examined and, when needed, checked by him. Moreover he attended to the transport of the apparatus to Rotterdam and, in concert with Naval Lieutenant Perks, took care of an effective mounting and stowing away of the instruments on board of the „Snellius”. For the assistance, given to us by the staff and the personnel of the Meteorological Institute I offer my sincere thanks to the Director, Prof. Dr. E. van Everdingen and to Dr. C. Schoute. Dr. Hardon who was first introduced into the scientific staff in May 1928 as chemical oceanographer, with Dr. Boelman, devoted every care to a practical arrangement of the chemical laboratory. In August 1928 the ship took the water. Mrs. van Riel performed the christening ceremony after H. M. the Queen had given her the name of „Willebrord Snellius” from the Netherlands Professor (1580—1626), celebrated for his work in the field of mathematics, triangulation and navigation. In the end of January 1929 the ship was officially put in commission at Rotterdam and shortly after she was inspected by the members of the Snellius Committee and by other visitors, who took an interest in our work.

G. THE TRIAL TRIP OF THE EXPEDITION SHIP IN THE NORTH SEA AND ENGLISH CHANNEL

This trial trip, which was undertaken so as to get acquainted with the peculiarities of the vessel and the working of the various parts, was also made use of to test the efficiency of the oceanographic apparatus and instruments, so that in case any deficiencies were found they could be corrected in

Holland before starting on the long voyage. Some idea could be formed at the same time as to whether the methods of mounting and packing the instruments, arranging the laboratories and the composition of formulars and registers were all likely to prove satisfactory. The leader, the two chemists and the physicist took part in the trial trip.

On the afternoon of Feb. 4th the ship cast loose from the Park-kade in Rotterdam, and after the boats had been raised, she steamed down the river. The same night the first surface water samples and surface temperatures were taken, so that the next day an immediate beginning could be made in the laboratory.

The first oceanographic observations were made on Feb. 5th near the Sandettié light-ship and in the eastern part of the English Channel, at small depths. The automatic brake of the Lucas sounding machine, Pl. IV, did not work very well at first, but after it had been readjusted there were no further difficulties with it. For bottom samples we used a T.L. Ekman bottom sampler, Pl. IV, improved by V. W. Ekman (13) and O. Pratje (14); further a Sigsbee-lead, Fig. 1, and a Monaco-sampler, Pl. IV, in case of hard bottom. The first mentioned

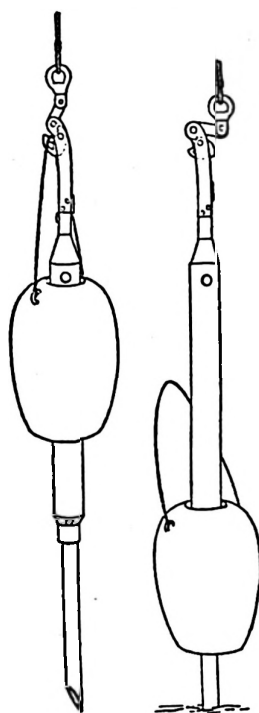


Fig. 1. Sigsbee-lead with slip arrangement, used at great depth.

instrument, consisting of a steel tube about 2 metres in length with an internal diameter of 30 or 20 mm, loaded with weights up to 30—35 kg, owing to the nature of the bottom, delivered no results. Judging by the amount of water contained in the tube the instrument appeared to be well closed. The Monaco-sampler, run out on a piano wire of 1 mm like the sounding tube, is more suited to the purpose when the sea bottom is of hard material; it brought up a little sand, broken shells and small pebbles. The instrument will be made heavier as the wire ran out very slowly. No faults were found in the thermometers and water bottles, Pl. V, used for raising samples of sea water and determining the temperature at various depths. They were let out on a wire of 4 mm diameter.

After favourable results had been obtained at greater depths also, wire soundings were taken outside the English Channel at a depth of 1740 m in which a water bottle and thermometers, Pl. V, were attached to the wire above the Ekman-sampler. This wire sounding was followed by a serial observation in which seven water bottles brought up at the same time seven samples at different niveaus between the surface and the bottom of the sea with the temperatures belonging to them. The sampler brought us a bottom sample bored out from the sea floor, of 15 cm length; the other instruments also functioned satisfactorily.

The efficiency of the simple Sigsbee-lead, Fig. 1, was demonstrated by a bottom sample produced on Feb. 8th at a depth of 1200 m. The sounding tube contained a core of grey clay of almost 1 dm length. The weight in this case was attached at the core tube and did not remain behind, as it usually does.

The galvanometer of the surface temperature apparatus, Pl. VI, proved to be very sensitive to the rolling of the ship so that in bad weather the registration was not dependable. This defect could be redressed by mounting the apparatus two decks lower.

When the chemical laboratory, Pl. VI, was taken into use, it was seen that certain alterations would be advisable.

Both of the echo apparatus ¹⁾ were satisfactory on the whole; in the anchor apparatus some necessary alterations had to be made.

The weather conditions so far had been fairly good, so that it could not be said how the vessel constructed for the comparatively calm waters of the tropical seas would conduct itself with storm in the open ocean. But after having passed the Straits of Dover, we were speedily caught by the strong east wind, which in the remarkable cold winter of 1929, reduced the temperature of the North sea to far below zero. The water breaking over us formed to ice on the forecastle, presenting a very striking and unusual picture, Pl. VII.

On Feb. 12th, when approaching the roads of Den Helder, the ship was caught fast in the

¹⁾ For description see Ch. II.

floating ice. Luckily at ebb tide we became free again and the following morning could moor in the ice-free harbour of Ymuiden. On Feb. 14th a second attempt was made to reach Den Helder, this time successfully; after a last struggle with the heavy floating ice in the harbour, Pl. VII, the ship was moored until the voyage to Netherlands India should begin. During the voyage out we should have ample opportunity for practise in making observations and we should profit by the experience we had gained on our trial trip.

H. THE VOYAGE TO THE NETHERLANDS EAST-INDIES

On March 9th H.M.S. „Willebrord Snellius” lay in the harbour of Den Helder, ready to sail, carefully equipped and in order for the comprehensive programme of research in the deep seas of the Indian Archipelago and the adjacent areas of the Pacific and Indian Oceans. I cannot express sufficient appreciation of the cordial relations in which I had worked with the Snellius Committee during the last year under the chairmanship of Dr. D. Fock. Let me here render a special word of thanks to the secretary of the Committee, Captain J. L. H. Luymes R. N., chief of the Hydrographic Department, who not only gave the initiative to the whole expedition by his original suggestion, but during the whole time of preparation was always ready to assist me with council and encouragement.

The harbour of Den Helder presented the usual spectacle characteristic of the departure of a naval vessel for the Indies. The quay was crowded with friends and relations taking leave of those who were departing and jostling one another in the attempt to say one more last word of farewell. In the name of the Committee Prof. Dr. E. van Everdingen, the late Prof. Dr. H. F. Nierstrasz and Captain J. L. H. Luymes had come on board to wish us a successful and pleasant voyage.

After Vice-Admiral L. J. Quant, Pl. VII, had addressed a cordial word of parting to those on board, the „Willebrord Snellius” steamed out of harbour at 13.30 on the 9th of March. There was a thick fog, so that the ship was lost to the eye of the crowd collected ashore, while the music of the naval band playing there could still be heard on board.

The whole crew was on board and all the members of the staff with the exception of Mrs. van Riel, who would join the vessel at Algiers.

The weather remained quiet and foggy, but the following day the mist cleared up and everything indicated steady weather. This enabled the non-sailors to get accustomed to their new surroundings without being troubled by sea sickness, and very soon to take up their various duties.

The first undertaking was to put the chemical laboratory into perfect order, so that the naval analysts could begin at once to practise the determination of oxygen and salinity of the sea water. They had already been familiarised with the work to some extent by a preliminary training in Utrecht and Den Helder.

The samples to be examined at first were taken from the surface, being raised every two hours, while the temperature of this water was determined by the officer of the watch. An opportunity to examine the deeper layers to a depth of about 2000 m was presented at Cape Finisterre.¹⁾

The weather conditions remained favourable, in accordance with reports, which reached us from Holland through the Director of the Branch Office of the „Koninklijk Nederlandsch Meteorologisch Instituut” (Meteorological Office), at Amsterdam. On board, to gain a more complete view of the weather conditions, synoptic weather reports from a few collecting stations were entered on a chart at least once a day.

After rounding Cape St. Vincent, however, a sudden change set in. While the sky remained clear and the barometric pressure only showed small fluctuations, wind and sea rose so violently that we were unable to steer a straight course and were obliged to tack like a sailing vessel.

On the evening of March 18th the port of Cadiz was sought, to await more favourable circumstances. As there was no improvement after 3 days, another attempt was made to pass Gibraltar strait, in spite of the storm blowing from the east. This was accomplished with success.

The loss of three days and the bad weather conditions prevented us from carrying out observations on an oceanographic vertical cross-section in front of, and a vertical section along

¹⁾ The results of the surface and serial observations on the outward voyage are included in the Appendix.

the axis of Gibraltar strait and moreover the intended anchor station before the Strait at about 700 m depth.

After passing Tarifa, wind and sea calmed down rapidly, as was to be expected, and the conditions became favourable. Shortly before entering the harbour of Algiers, on March 23rd, the collection of surface water samples and determination of their temperature was stopped.

The ship, in accordance with the plan, lay for five days in Algiers, Pl. VII, during which time the members of the staff had ample opportunity to explore the town and to make the celebrated tour to Blida (Gorge de la Chiffa). The weather however, was not favourable and did not show off the beautiful country to advantage.

The consul, who was absent, had sent me his best wishes for our success in writing, and had informed the Governor General and the oceanographic circles of the presence of the members of the expedition on board, so that we could get into contact.

On March 28th at 2 o'clock p. m. we left the port of Algiers, after which the observations of temperature and salinity of the surface water were immediately continued. The following days serial observations were carried out both in the eastern and western basins to a depth of 900 to 2000 m preceded by wire soundings in over 1000 to 3000 m. These observations were not only made for practice in the use of the Lucas sounding machine and the serial machines, but in addition to the surface samples also deep samples could be examined to determine not only salinity, but also other chemical properties. The International Council for the investigation of the sea had requested me on the voyage to the East-Indies to collect water samples for the determination of the sulfate-chlorinity ratio in sea water. This determination was to be made by a special person Prof. Thomas G. Thompson of the University of Washington, Seattle. (15). Moreover Dr. J. F. Reith, chemist to the commission for combating Struma in Holland had requested me to send a few samples of surface and depth water to the „Centraal Laboratorium voor Volksgezondheid" (Central Laboratory for public health) at Utrecht, for examination of the iodine content.

We replied to both requests; in the Mediterranean at five and two stations respectively; besides surface water, samples were raised from a depth of 900 m. For this purpose a 4-litre water bottle was used for the first time.

The serial observations were now again preceded by wire soundings; instead of the costly Ekman bottom samplers and Nansen water bottles a Sigsbee-lead was used with a weight attached of 25 kg and the less expensive Sigsbee water samplers. During the operations on April 2nd we lost the Sigsbee-lead with a small Sigsbee water bottle, a thermometer frame with two thermometers and 2300 m wire. The cause of this was probably a kink in the twisted wire. The Sigsbee-lead yielded bottom samples, to a maximum length of 45 cm.

The weather conditions were pretty favourable. A deep depression from North Italy, first descending to Sicily, afterwards drew off in a N.E. direction. But it remained behind the ship, causing wind and waves to come from the S.W., the former increasing the speed of the ship while a small sail astern did good service. In the eastern part of the Mediterranean, however, the wind after a period of calm, gradually veered to the E. rising in force to 5 to 6 Beaufort, and causing a troublesome sea in which we again lost the time we had previously gained. The weather reports from shore stations were received as far as possible and entered in the chart, so as to get information about the pressure distribution.

From April 5th to 10th the ship lay at Alexandria. All the members of the expedition and part of the crew, Pl. VIII, took advantage of the occasion to pay a visit to Cairo. After station 14 had been accomplished between Alexandria and Port Said in the vicinity of la Rosetta, the ship was moored in Port Said on April 11th where fuel was taken in.

Next morning the passage through the Suez canal was begun. The temperature, which during the whole voyage through the Mediterranean had been usually below 15° C began to rise rapidly till the thermometer stood at 28° C. We began at last to have a summer-like feeling and we were seized with a desire to exchange our winter clothes for lighter garments. Soon everyone appeared on deck in white, lending a cheerful aspect to the scene, and being more in accordance with the appearance of the white painted ship. Pl. VIII.

As we moored in one of the many widenings in the canal, so as to give other ships the opportunity of passing, the commander had given permission to bathe. Just as the aspirants were ready

to go overboard, the canal pilot gave orders to steam ahead, but the chef d'équipage consoled the crew by saying: „Cheer up, lads, when you come back here, then you can have your swim”.

Owing to the strong evaporation and the small rainfall the salinity of the water in the canal is exceptionally high. A sample taken in the Great Bitter lake showed it to be 45.08‰, while in the open ocean about 35 gr per kg sea water is found.

In the evening of April 12th we passed Suez. So far fully 200 double chlorine titrations had been made, from now onwards also oxygen analyses were made so that the chemical laboratory assumed a busy aspect. In the Gulf of Suez the examination of the surface water samples taken every 2 hours was continued from the 12th of April and several samples were taken for Prof. Thompson and Dr. Reith. In the forenoon of April 15th station 16 was accomplished, when the Sigsbee tube raised a sample of record length (61 cm). Water investigation was now extended to the bottom so that the water bottles had to be used in two series.

In the afternoon practise was held in the use of the large plankton tow-net, Pl. VIII, with which we fished at about 100 m depth for half an hour. This first official biological catch had been preceded by others (from the surface) which needed less time and less members of the crew in attendance. A diversion was caused by the catch of two sharks which engaged the whole ship, and in which the seaman gave full expression to his unfriendly feelings towards these inhabitants of the sea, Pl. VIII.

The following day at station 17 a plankton-catcher was tested. The water in the neighbourhood is pumped through a net of wire gauze for about half an hour after a „messenger” has hit the upper side of the instrument. The organisms that live in a known mass of water at a precisely determined niveau remain in the net. April 17th everything was made ready to anchor in a depth of about 1000 m. Unfortunately the breaking of one of the cogwheels in the anchor machine frustrated our intention.

At station 18 an attempt was made to better the record bottom-sample by using an Ekman bottom sampler weighted to about 38 kg. But the sample raised proved to be no more than 31 cm.

The observations concerning temperature, salinity and oxygen content are found in the Appendix. The results were communicated in the „Annalen der Hydrographie und Maritimen Meteorologie” (16). All the observations in the Red sea and the Gulf of Aden indicated an inflow at the surface of less saline water from the Indian Ocean, of which the salinity, owing to evaporation, constantly increases towards the north. The heavier water sinks gradually in the northern part of the Red sea to deeper layers and occasionally flows back to the south over the sill in the Strait of Bab-el-Mandeb, into the Gulf of Aden and the Indian Ocean. The last appeared very clearly from the observations made on April 19th in the Strait from the great difference in salinity of the water in the upper layers (36‰) and near the bottom (40‰). The influence of this warm strongly saline current is apparent in the Gulf of Aden to beyond Aden in the vertical temperature and salinity distribution. This corresponds to the conditions on the sill between the Mediterranean and the Atlantic at Gibraltar strait.

The plan to trace this highly saline current by observations at a short distance from Bab-el-Mandeb in the Gulf of Aden, had to be abandoned owing to the amount of work to be done on the ship. A dredging practice had to be abandoned also. North of Jebel Teir an area was sounded with the echo-sounder, where some irregularities in the form of the sea floor were suspected. No definite shallows were found, but the conjecture as to the irregularity proved to be correct. (see p. 19).

In the afternoon of April 20th we anchored in the road of Aden and the same evening the fuel tanks were filled, Pl. IX. During our stay there, the celebrated „tanks” were of course inspected; a visit to an Arabian village in the neighbourhood of Aden, had great charm for those who were unacquainted with the tropics. The English Club, which had offered us hospitality, supplied us with a cool drink after our hot excursion and a pleasant rest near the shore.

On April 23rd we said good-bye to Aden, to begin our long journey across the Indian Ocean. Before leaving Aden, the Lucas sounding machine was provided with a drum over which 11000 m piano wire had been reeled in Holland. When taking a sounding at station 20 (Appendix) it appeared that the wire had not been wound with sufficient tension, so that when paying out, the wire cut into the lower layers and would not run further. The wire that had been wound up at a very

low temperature, had evidently stretched in the much higher temperature and come to lie loosely round the drum. There was nothing to be done but to abandon the sounding and to re-wind the 10000 m wire with the proper tension, a lengthy piece of work, requiring the utmost care. At station 20, therefore, we had to be satisfied with a serial observation to a depth of 1100 m at eleven niveaux.

The number of surface observations, which up to Aden had been 12 per day, was now reduced to the half, as the naval analysts were only available for three days in the week.

On April 27th and 30th in the northern part of the Indian Ocean stations 21 and 22 in about 4700 and 4000 m respectively, were thoroughly carried out. No oceanographic instruments were attached above the Sigsbee-lead, however, as it was not impossible that the piano wire might have suffered from the paying out and re-winding so that there was some chance of loosing instruments. The results obtained by serial observations about the vertical distribution of temperature, salinity and oxygen, here also, as in the Atlantic Ocean, indicated a horizontal circulation. (16, 17, 18, 19, 20). The intended oceanographic observations upon the ridge of the Maldives in the $1\frac{1}{2}^{\circ}$ -channel, had to be omitted because of the great amount of work to be carried out by the naval personnel.

As after passing Socotra the course was set in a more southerly direction to benefit by more favourable weather conditions, we met few other ships and the track in the western part offered little variety. A large P & O steamer, which thought the small „Snellius” looked rather lost in the vast expanse of sea, inquired solicitously „Is the Ocean wide enough for you?”

The long track to Sumatra was broken by a visit to the Suvadiva Atoll, one of the largest of the Maldive Group and 44 miles in length north and south by 34 miles in breadth. The islands on the boundary are numerous and low; coconut trees on them appear on first approach to be growing out of the water, Pl. IX. The islands are governed by a sultan who acknowledges the suzerainty of the British Government. The inhabitants who carry on a considerable trade with Ceylon and the British possessions in India, are not allowed to trade directly with foreigners, the whole of the export and import is conducted at Male or Sultans Island.

After steaming through the islands on May 3rd we anchored on the inside in the lagoon in the vicinity of a small village. This area was an interesting field of investigation for the geologist and the biologist. The observations they made on various islands and coral reefs were not very extensive, but furnished sufficient material for a comparison of this atoll with others in the Netherlands Indies.

The village was not very interesting; an old gentlemen armed with a blue head cloth and an umbrella, apparently the head-man, came to greet us on the shore, followed by the male portion of the inhabitants, Pl. IX. After a short walk over the island, during which the head-man presented the only lady in the company, Mrs. van Riel, with a blade of grass by way of a floral offering, we were invited to take seats outside one of the dwellings. The visit did not last long as we did not understand their language; the friendly but inquisitive villagers, who did not appear to pay much respect to the authority of the old man, pressed upon us from all sides and the great quantities of flies did not enhance the attractions of the place, so that we hastily returned to our ship. When it had become dark the commander rewarded their friendly intentions by a magnificent display of light on the shore in front of the village with the search-light of the „Snellius”.

On the afternoon of May 4th the anchor was weighed and before sun-set we were on the east side of the circle of islands in the Indian Ocean. On Sunday 5th the ship crossed the equator, where we stopped and Neptune was officially received by the commander. The sea-god brought a present for several of us; to Mrs. van Riel, who had told the steward the day before, that sardines would be appreciated on the lunch table, he offered a dainty tin of these delicacies; the commander received a box of echos, which had not returned during echo-sounding and the leader of the expedition was presented with water bottles, which at station 13 in the Mediterranean had been lost by the breaking of the sounding wire, as a reward for not being superstitious and not changing the number 13 to 12a. Neptune paid many kind attentions to the rest of those on board, Pl. IX, so that after the members of the expedition who were passing the line for the first time, had been submitted to all the traditional accompanying ceremonial, he was bidden a grateful farewell.

On May 5th and 10th stations 23 and 24 were fully worked off in the eastern part of the Indian Ocean, at a depth of about 4800 m (Appendix). In this second part of the Indian Ocean track the naval officers and men told off for taking echo-soundings were practised as much as possible. The observations were made at the request of the Vice Admiral of the Fleet in the Netherlands East-Indies

regularly from 84° E. up to Padang. From station 21 to Padang the meteorological observations were made on board, according to the programme that had been laid down for the whole duration of the expedition in the Archipelago. After the last station on the outward journey had been finished on May 10th, the observations with surface water samples and the determination of temperature terminated too. The results, running from March 15th to May 10th 1929, may be found in the Appendix together with the serial observations at stations 9 to 24.

The weather conditions were on the whole favourable in the eastern part of the Ocean, although occasionally a moderate swell from the south and west made presence on the ship somewhat less agreeable. We were, therefore, thankful when the coast of Sumatra came in sight and the ship anchored in Emma haven (Padang) on May 12th. Here we lay in a bay of the coast, surrounded by verdant hills, which presented a most beautiful panorama from aboard. Coming ashore it was a joy to feel firm ground under foot after the long voyage, a pleasure that was increased by seeing the beautiful surroundings of Padang, during a trip to Fort de Kock. The first impression thus gained of Netherlands East-India will be a radiant memory for many for all their lives.

I. SOME REMARKS SUGGESTED BY OUR EXPERIENCE ON THE OUTWARD VOYAGE

On our arrival in Padang, the time of probation for our various instruments, in preparation for the research we were to undertake, may be regarded as concluded. There would be no further opportunity for experimenting on the voyage from Padang to Tandjong Priok (Batavia), as every one would be too busy getting the vessel into perfect order, outside and inside. On a sea voyage there are not sufficient facilities for this, and in this case it was so in particular, as part of the crew had to be available during the outward journey for carrying out observations. I have no doubt that Commander Pinke sometimes found it difficult to reconcile himself to this fact, but he was also convinced that good practise would be of the greatest benefit to the future research. Moreover, during the journey it became obvious what alterations would be necessary in the mounting and handling of instruments and apparatus, arrangement of laboratories and methods of observation, etc. A trial trip of this sort seems to me essential before undertaking any extensive sea research. The only thing in which we had not had any experiences was in anchoring in very deep water, and consequently we had not been able to experiment thoroughly with the current-meters.

During the trial trip in the English Channel as well as during the outward voyage to the East-Indies, Hamaker had paid much attention to the exact working of all instruments and their upkeep. With the assistance of the torpedo petty-officer small repairs were made on board, improvements or alterations of more importance were recorded and postponed till our stay at Soerabaia.

It is not necessary to relate in detail all the improvements which were carried out at the Marine Docks in Soerabaia, with the kind assistance of the Marine authorities and especially of the Director of the Docks, Mr. F. Diephuis. We will confine ourselves to a few remarks which may be found of use in any future research.

Winches for serial observations. The two winches which were used for raising water samples from various depths and the determinations of temperature in these niveaux, acted splendidly, after they had been thoroughly looked over at Alexandria. It is important to mount the machines so that they are exposed as little as possible to sea water. The use of a dynamometer to test the tension in the wire is very desirable. From the place where the machine is served, the dynamometer, the measuring wheel and the checking instruments of the electro-motor must be observable. The diameter of the measuring wheel must be controlled.

Lucas sounding machine. It is desirable for this machine to have a reserve drum wound with wire constantly in readiness, and to be sure beforehand that a change can be easily made. Here too a tension-meter should be used in the wire which will give warning before attaining the breaking strain when hauling in the steel wire of 1 mm diameter. It is very important to make sure that the measuring wheel belonging to the apparatus is of the proper circumference.

Reversing thermometers, water bottles and bottom-samplers. In the thermometers it occasionally happened that the mercury ran on after the thermometers had reversed; the water bottles functioned excellently. At first we had some trouble with the apparatus which closes the bot-

tom of the tube of the Ekman sampler when the tube strikes the bottom; the weight did not slide down so that we ran the risk of losing the sample.

Meteorological instruments and surface thermograph. The meteorological registering instruments (barograph, thermograph and hygrograph) were mounted in a screen, which was hung up above the compass-deck by means of a pair of springs (see Ch. II). This method of suspension proved at once to be insufficiently elastic so that the lines on the diagrams were too thick. It proved to be desirable to place the instruments in the screen upon felt or some other buoyant material to subdue the vibration and to attach soft springs to the four corners of the screen to lessen the swinging with the movements of the ship.

The surface thermograph must be suspended in gimbals as low as possible in the ship, as otherwise any disturbance of the sea makes the observations less accurate.

Concerning echo-soundings and the determination of the ship's position the following is reported by commander Pinke. (see Ch. II).

Echo-soundings. Of the two echo-sounding apparatus the Atlas-sounder proved satisfactory; the Hughes-sounder was not a success on the journey out. The readings of the Atlas-sounder taken by 10 different persons at various stations were compared for each station separately. When there was a distinct echo the extreme results did not differ more than 20 m, the result was less satisfactory with an indistinct echo. The seamen who were told off to take the readings steadily improved in skill and accuracy.

A discrepancy between the wire and echo-soundings gave rise to an investigation of the speed of the motor of the dial plate. The dial, instead of rotating in 1.611 sec, sounding velocity 1490 m/sec, took 1.564 sec, corresponding with a velocity of 1537.5 m/sec. Probably the indications of the frequency meter were influenced by the higher temperature in the tropics. The total number of hours devoted to echo-sounding practise was 257.

Position. In the Atlantic Ocean and the Mediterranean circumstances were not favourable for astronomical determination of the ship's position. But in the Red sea and the Indian Ocean almost every day it was possible to determine the position by fixes of the sun and stars. Once or twice a transit of Venus could be observed in day time. The observed position was always determined by two officers; as far as possible 4 stars were observed at twilight which were about 90° in azimuth apart and of which each pair stood at the same height. This method reduced errors to the minimum.

The biological activities on the outward voyage are described by Prof. Boschma as follows:

During the journey out the various plankton nets were made use of a few times, principally to see if it would be advisable to make any alterations in the apparatus before the real beginning of the expedition. They were tested in the Red sea and in the Indian Ocean, as the material collected here would probably be of more value than that taken from the Atlantic Ocean, and the Mediterranean; the latter being biologically much better known than the former.

On April 13th we collected a few specimens of *Aurelia maldivensis* Bigelow at 27° 28.5' N. and 34° 0.5' E. Later on the same day the ship passed through large numbers of apparently the same species of medusa. On April 15th plankton was collected from approximately 100 m (station 16a, 22° 28.5' N. and 37° 29.0' E. Straminpose, 300 m wire).

At station 17 (Red sea) on April 16th a sample was taken with Pettersson's plankton-catcher on the wire rope of the serial machine at 450 m depth. Later fishing was done with a vertical closing net at a depth of 1000 to 555 m.

In the Indian Ocean on April 30th plankton was collected from deep water (station 22), closing net, 1000 to 555 m. On May 3rd and 4th collecting on the reefs and dredging in the lagoon. (Suvadiva Atoll, Maldives Islands). The dredging had little success: the dredge was badly torn on the rough bottom. Besides the above mentioned apparatus, a plankton-net of the Borgert type was tried at a speed of 8 seamiles. Moreover several times large plankton organisms were collected from the surface of the water with a hand net. It appeared from the above mentioned trials that the biological apparatus would answer their purposes during the expedition.

Concerning the geological observations Dr. Kuenen reports as follows:

Bottom samples. In all 15 soundings were taken on the outward voyage. Once the wire broke after a few hundred metres had been reeled in. Three soundings were taken with the Ekman-

tube of 2 cm diameter; the length of the samples was rather disappointing as they were only 31 cm, 32 cm and 20 cm. One sounding was taken with the Ekman-tube of 3 cm diameter, which raised a sample of 38 cm length. On the other hand the soundings with the Sigsbee-sampler yielded better results than had been expected, the average length of the 6 samples being 38 cm. Twice only the sample was not retained by the Sigsbee-tube; on the threshold of the Red sea, where the strong current rendered the sediment too coarse, and for some unknown reason in the Indian Ocean. With the Monaco-catcher two samples were brought up, one in the Nile delta from 30 metres of water, and one on the threshold of the Red sea, when the Sigsbee-tube had come up empty. In the first case everything functioned well, but in the second only a very small quantity was raised. By making the instrument heavier and placing a weight round the rod of the catcher, Pl. IV, later soundings yielded better results.

The samples were collected in glass tubes, where they were hermetically sealed up in the original damp condition, to be investigated at home. The small amount that escaped during the process, was collected and used for immediate examination. As it is extremely difficult to weigh things accurately on board, these remnants were only examined qualitatively to ascertain the nature of the sediment. In the Mediterranean samples were brought up very rich in pterapoden, but it could not be said definitely whether they belonged to the pteropoden ooze or to blue mud, rich in pteropoden.

The only deviation from the current deep-sea ooze chart that was found, was the presence of radiolarian ooze at station 22 at 3° 48' N. and 63° 48' E. in the Indian Ocean. This is probably an isolated patch in the midst of the extensive area of globigerina ooze of the N.W. Indian Ocean, just as further to the S.W. radiolarian ooze is found over a small area.

It is further worth mentioning that S.E. of Malta at 35° 13' N. and 17° 0' E. a sample was raised in which five clearly separated strata could be distinguished.

Bottom formation. The echo-soundings have already yielded various interesting results. In the S. E. portion of the Red sea to the north of Jebel Teir a large number of soundings were taken. Here the remarkable phenomenon appeared, that the depth remained almost constant, sometimes for several kilometres and then suddenly decreased or increased by some hundreds of metres. Those in charge of the echo-soundings were of course not yet sufficiently routinized in their work to understand that in such a case the soundings should immediately be taken as close together as possible. In one case Dr. Kuenen ascertained that the depth remained quite constant for several minutes, after which the echo suddenly disappeared, and after about 10 seconds registered three hundred metres more. This really seems to indicate a vertical step. In another case the echo remained audible but the slope was about 45°. Results like this cannot be obtained by wire soundings, as the drifting of the ship during the paying out and reeling in cannot be checked in mid ocean so that a vertical step at great depths can never be positively asserted.

Geologically this result is important as the steps in all probability are caused by faulting, although the different steps cannot be connected in a simple system of fault lines. The hypothesis that the trough-valley of the Rhine with its numerous faults and the Red sea are both of a similar origin, receives great support from these soundings.

The series of soundings right through the Indian Ocean also yielded important results. They begin with an exact profile of the continental shelf from Africa to deep ocean. The slope begins suddenly at the 100-metre line, not the 100-fathoms line, and is at the maximum 7°. The mean slope is 2°—3°. After that a sounding was made every hour, while several times a shallow was sounded more minutely. Up to the Maldivé Islands the bottom revealed a peculiar character. Fairly even areas of many tens of kilometres length and 3000—4000 m depth were suddenly broken by very steep rises of 1000—2000 m height. Slopes of 10°—15° along a distance of a few kilometres may be found here. It is an open question whether these are elongated ridges or detached elevations. The even floor that adjoins these shallows, seems to indicate volcanos rather than foldings, while the flat top of one rise is possibly a submerged atoll, such as Davies believed to exist here. The other elevations might also be interpreted as submerged atolls, by assuming that we only sailed over the external slope without touching the flat top. In total on this track, which is a good 2000 km long, about 15 such shallows were detected.

The profile of the external slope of Suvadiva was minutely sounded, which disclosed the

unexpected peculiarity that the slope did not appear to be even, but in contrast to the almost even slopes of the shallows mentioned above changed suddenly. It cannot be stated with certainty what the geological meaning of these steps is; they may be submerged reef-terraces.

The profile from the Maldive Islands to Padang is of a totally different character. Directly following the Maldive Islands a very even floor begins at about 4600—4800 m depth. This continues half way to the coast of Sumatra, where a shallow of 2200 m is found, which is followed by a remarkably even bottom. It is very improbable that the occurrence of so many more shallows in the west can be attributed to accident. Before the 5600 m deep trough west of Siberoet the bottom rises steeply to 500 m and then slowly declines to the greatest depth. Then follows a ridge on which Siberoet is situated of which the slope is broken by a flat piece at 800 m of some kilometres breadth, and finally the trough before Padang in which a maximum depth of 1600 m was found.

This profile through the Indian Ocean also lends support to the theory that the deep-sea floor is strongly accidented with hardly less marked features than the continents.

J. STAY IN JAVA BEFORE THE COMMENCEMENT OF THE RESEARCH

After leaving Padang on May 17th en route for Batavia, Commander Pinke gave those on board a great treat, by choosing the route through the beautiful Taroesan bay, steaming between the numerous islands which lie along the coast of Sumatra south of Padang. The fairway is deep and the coasts are steep so that we passed quite close to the islands, and each new course revealed a new and lovely panorama.

On May 20th we moored in the harbour of Tandjong Priok (Batavia). Here the expedition was welcomed by Lieutenant 1st class P. J. Feteris R. N. in the name of the Rear Admiral, Commander in Chief; Mr. S. H. Leegstra, chief inspector of shipping as representative of the Indian Committee and by Dr. C. A. van den Bosch in the name of the „Koninklijk Magnetisch en Meteorologisch Observatorium” (Royal Magn. and Meteor. Observatory), an attention which we appreciated very highly. A word of thanks is here also due to the Executive Committee of the Fourth Pacific Science Congress, who on our arrival appointed the members of the staff and some of the officers as members of the Congress. It was only a pity that the ship had not arrived a week earlier in Tandjong Priok as we should then have been able to attend the meetings, begun a few days previously in Bandoeng with more leisure and more profit. The excursions held after the meetings, however, lent an opportunity of renewing acquaintances with colleagues and forming new friendships.

At one of the meetings of the oceanographic section at Bandoeng I was invited to address the congress upon the object, the scope and the methods of the expedition. It had been arranged beforehand that during our short stay in Batavia some official calls should be made. In the absence of His Exc. the Governor General, the most important visit was to the Commander in Chief, Rear Admiral A. ten Broecke Hoekstra, to whose co-operation during its preparation the expedition owed much, and who showed great interest in our work during our investigations. The admiral was so kind as to treat us shortly after our arrival to a dinner of welcome and to wish us all success on our future work. A letter for the Governor General brought by me expressed the thanks of the Snellius Committee for the great support given by the Netherlands Indian Government.

The Director of the Magn. and Meteor. Observatory at Batavia, Prof. Dr. Boerema, was so kind as to give us the loan of some instruments; we owe many thanks to Dr. Berlage of the Observatory for gauging the instruments for determination of the sun's radiation, so that we could see if there was any difference with the gauging done in Holland. (Vol. III).

On May 27th the „Snellius” left Tandjong Priok and on May 30th arrived at Soerabaia. The necessary overhauling of the ship proved to be a more lengthy business than had been anticipated so that the expedition proper could not start till the end of July.

We made a virtue of necessity and the forced delay was utilised to the best of our powers. A few more changes were made in the chemical laboratory, the most important being an improvement of the ventilation. The oceanographic instruments were taken ashore and thoroughly inspected, after which, with the welcome help of the naval authorities some modifications were introduced. The apparatus on board was, moreover, thoroughly overhauled and where necessary repaired. On the programme of work for the various replenishing stations stood the control of the zero of the

reversing thermometers. Errors may arise from a change in the volume of the thermometer bulb after the manufacture of the instrument and the subsequent gauging. This testing was begun in Soerabaia but the high temperature (and at first impure ice) caused considerable difficulties, and we gratefully accepted the offer made by the Sugar Experiment Station at Pasoeroean to complete it on their premises. Here four cells were put at our disposal, which were kept at temperatures of minus 2°, + 2°, + 10° and + 20° C. By combining two of these cells the thermometers could be read at leisure in a temperature of 5°—7° C. while the supply of planed ice from distilled water diminished very little. By this method Dr. Hamaker verified 80 reversing thermometers in four days. No great difference with the original data were found; in only 2 thermometers a maximum error of 0.02° was found (for particulars see Vol. II, Part. 1).

It was very satisfactory that this important work could be carried out under the most favourable circumstances. Several days of work would have been occupied by it at the replenishing stations where it might have been difficult to obtain pure ice. Moreover every thermometer had now been inspected, and they could be divided into classes, according to whether they showed less or more „vagaries”. Let me take this opportunity of expressing my thanks to the Experiment Station, especially the director of the Technological Dept. Dr. Honig, for their hospitality.

Besides the alterations on board which were ordered by the naval authorities, many improvements were made in the arrangement of the ship, the desirability of which had been shown during the voyage out. There was now plenty of time for this. The only drawback was that owing to these changes, the conditions were not very favourable, when the expedition ship was visited by some 15 foreign members of the Pacific Science Congress, at Soerabaia.

The Nederlands crew, that had come out from Den Helder departed, except for the Officers and a few routined men. They were replaced by native sailors. The leader engaged as draughtsman and secretary G. Tampenawas, while as assistant to Prof. Boschma and Dr. Kuenen the mantri Erie and the mantri-surveyor Kartodihardjo embarked.

On July 25th the ship steamed out of harbour to the roads of Soerabaia, where the compasses were adjusted. After the numerous native workmen and coolies had left the ship the last touches could be given to its preparation and on July 27th, after a cordial word of farewell from the Naval Commander, Captain A. Vos, we steamed out, and passed the light-ship of the Westervaarwater at 12.53.

Here the work of the expedition proper commenced.

APPENDIX

OCEANOGRAPHIC OBSERVATIONS CARRIED OUT DURING THE VOYAGE FROM HOLLAND TO THE NETHERLANDS EAST-INDIES

As the oceanographic observations made on the trial trip in the North sea and English Channel are not considered to be sufficiently precise, we only give those results from the outward journey which were obtained after long practice.

Table I contains the temperature, salinity and density of surface samples, collected in the Atlantic Ocean, the Mediterranean, the Red sea and the Indian Ocean.

Table II contains the serial observations of temperature and salinity at stations 9—14 in the Atlantic Ocean and the Mediterranean, with the temperature and the salinity and oxygen content, determined at stations 16—19 in the Red sea, at station 20 in the Gulf of Aden and at stations 21—24 in the Indian Ocean.

As the accuracy of the salinity and oxygen content cannot be considered as accurate as those made in the area of research in the Indies we make the following remarks:

Salinity determinations. For particulars concerning the determinations we refer to Vol. II, Part I. Much time was devoted to training the analysts. Before we left Holland they had been given a course of instruction on shore, but they still needed practise in recognizing the exact colour at the end of the titrations. On the voyage to the East-Indies about 1600 chlorine titrations were made, inclusive 975 from 312 surface and 157 deeper samples. The further determinations consisted of:

1. Standard water titrations, which were taken after every 10 determinations and
2. Practise titrations for the analysts.

Figure 2 gives an idea of the accuracy of the salinity determinations of the above mentioned 469 water samples, in which a few of the titrations are omitted. The curve shows the frequency in 0.01‰ of the deviations of the titrations from the mean value for each water sample. The representation is slightly flattered as regards the deviation 0.00, as the deviations from the mean value were rounded off in 0.01‰ so that 0.005‰ was noted as 0 and as 0.01.

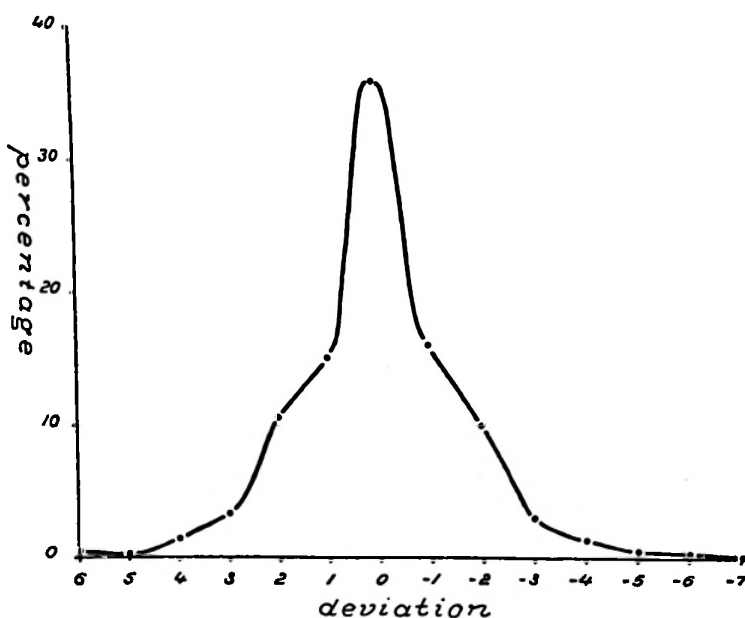


Fig. 2. Accuracy of salinity determinations on the outward voyage.

It can be seen from this figure that considerable deviations occur fairly often; of 975 titrations, 119 times a deviation of more than 0.02‰ from the mean value was found, that is about 12%.

Oxygen determinations. In Vol. II, Part I the method of making oxygen determinations is described. Before April 15th 1929 a great number of oxygen titrations were made for practise; after that date the oxygen amount of 94 water samples was determined twice. The deviation of each determination from the mean value was calculated and rounded off in 0.01 cc/l. The curve in Fig. 3 shows the frequency of the deviations 0.00 to 0.06 cc/l. In 16 of the 188 determinations the deviation was greater than 0.06, thus 8.5%. The greatest deviation was 0.17.

For the accuracy of the oxygen determinations during the expedition, see Vol. II, Part I.

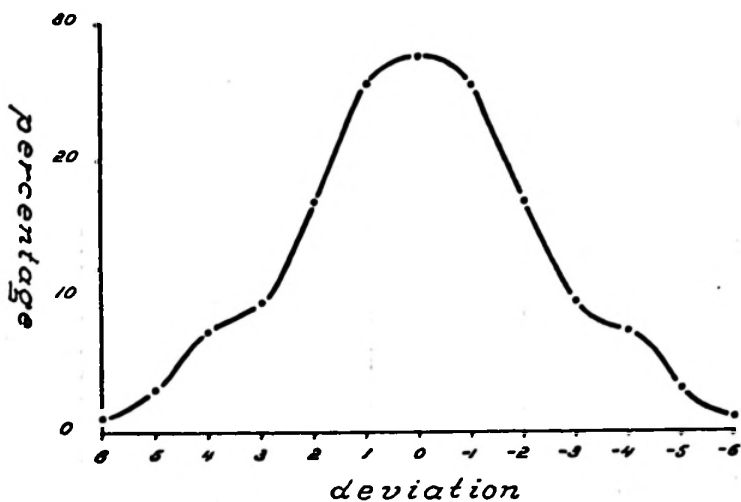


Fig. 3. Accuracy of oxygen determinations on the outward voyage.

Temperature in situ, Salinity and Oxygen observations in the Atlantic Ocean, Mediterranean sea, Red sea and Indian Ocean during the voyage of H.M.S. „Willebrord Snellius” to the Netherlands East-Indies ¹⁾.

TABLE I. SURFACE-OBSERVATIONS.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. W.	Temp.	Salinity	Density	
1929	° ' "	° ' "	°C.	‰	σ _t	
III. 15. 10	43 5	9 20	13.0	35.57	26.86	Atlantic Ocean.
— „ 12	42 47	24	14.1	34.61	25.89	
— „ 14	30	24	.3	35.61	26.61	
— „ 16	15	25	.1	.48	.55	
— „ 18	41 58	27	.0	.62	.69	
— 16. 8	40 4	10 31	15.3	—	—	
— „ 10	39 48	9 32	.3	36.04	.72	
— „ 12	20	37	.6	35.14	25.97	
— „ 14	4	35	16.1	34.65	.47	
— „ 16	38 45	33	15.8	35.46	26.17	
— „ 18	29	29	.5	34.85	25.76	
— „ 20	11	23	16.0	36.24	26.71	
— „ 22	37 53	24	15.7	.26	.80	
— 17. 0	34	15	.0	.22	.93	
— „ 2	21	10	.4	.26	.87	
— „ 4	4	8	14.5	35.90	.79	
— „ 6	36 56	8 56	.5	36.08	.92	
— „ 8	49	41	.5	.18	27.01	
— „ 10	46	31	15.6	.33	26.88	
— „ 12	45	28	.6	.26	.82	

¹⁾ The data in table II deviate, principally as far as concerns the bottom depths, from those published in the Ann. d. Hydr. usw. 1932, p. 401.

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. W.	Temp.	Salinity	Density	
1929	° ' "	° ' "	°C.	‰	σ_t	
III. 17. 14	36 42	8 21	15.8	36.35	26.84	Atlantic Ocean.
— " 16	39	15	16.2	.31	.72	
— " 18	32	13	15.0	.35	27.02	
— " 20	19	10	.2	.36	.00	
— " 22	10	6	.0	.36	.04	
— 18. 0	15	7 59	.5	.42	26.97	
— " 2	12	54	.2	.40	27.03	
— " 4	12	50	.0	.36	.04	
— " 6	18	41	.0	.36	.04	
— " 8	25	29	.7	.38	26.90	
— " 10	31	19	.5	.33	.90	
— " 12	37	11	.5	.33	.90	
— " 14	45	6 56	.7	.36	.89	
— " 16	41	55	.1	—	—	
— 21. —	—	—	14.8	.00	.81	Cadiz Harbour.
— " 10	27	18	.8	.45	27.16	
— " 12	13	13	—	.44	—	
— " 14	5	6	.3	.35	.18	
— " 16	35 59	5 55	.5	.29	.10	
— " 18	58	42	15.0	.45	.11	
— " 20	59	23	13.9	.31	.24	Mediterranean Sea.
— " 22	36 1	1	14.4	.56	.33	
— 22. 0	1	4 36	.4	.44	.23	
— " 2	1	12	.5	.47	.23	
— " 4	1	3 48	.5	.51	.26	
— " 6	35 59	17	.5	.76	.46	
— " 8	59	2 56	.6	.76	.44	
— " 10	36 3	29	.8	.53	.21	
— " 12	7	2	.4	.78	.49	
— " 14	10	1 36	.3	.96	.66	
— " 16	11	19	.4	37.41	.98	
— " 18	18	0 51	.7	36.91	.52	
— " 20	15	24	.6	.80	.47	
— " 22	22	Long. E. 5	.6	.83	.50	
— 23. 0	31	30	.5	.80	.49	
— " 2	41	54	.0	.85	.64	
— " 4	44	1 25	.8	.98	.56	
— " 6	46	44	15.2	37.00	.49	
— " 8	49	2 17 ^s	14.3	36.92	.63	
— " 10	50	45	.8	37.12	.67	
— " 12	50	3 4	15.2	36.06	26.76	
— 28. 16	52	17	16.0	.92	27.25	
— " 18	58	23	14.5	.14	26.97 ^s	
— " 20	37 3	50	13.9	.82	27.63	
— " 22	5	4 8	.9	.91	.69	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Density	
1929	° '	° '	°C.	‰	σ_t	
III. 29. 0	37 6	4 29	14.1	36.98	27.71	Mediterranean Sea.
— " 2	8	52	.3	.98	.67	
— " 4	9	5 11	.3	.96	.66	
— " 6	11	30	.2	.98	.69	
— " 8	12	52	.3	.98	.67	
— " 10	10	6 16	.4	.94	.62	
— " 12	12	35	.4	37.25	.85	
— " 16	13	55	13.5	.00	.86	
— " 18	11	7 12	.5	36.94	.81	
— " 20	12	31	—	.94	—	
— " 22	12	43	12.6	.92	.98	
— 30. 2	13	55	13.1	—	—	
— " 4	15	8 15	.2	.83	.79	
— " 6	16	36	.5	.87	.75	
— " 8	19	54	.2	.87	.81	
— " 10	20	9 10	.6	37.10	.91	
— " 12	25	27	.4	.05	.92	
— " 14	26	42	.1	.09	28.01	
— " 16	19	10 2	.4	.18	.01	
— " 18	14	20	.2	.01	27.93	
— " 20	15	39	.4	.21	28.04	
— " 22	12	11 0	.4	.03	27.91	
— 31. 0	7	19	.2	.19	28.07	
— " 2	1	39	.2	.19	.07	
— " 4	36 56	12 0	.2	36.85	27.80	
— " 6	49	20	.4	37.09	.94	
— " 8	44	35	.6	.34	28.09	
— " 10	38	53	.8	.36	.07	
— " 12	37	59	.7	.36	.09	
— " 14	31	13 19	.8	.34	.05	
— " 16	24	39	14.1	.30	27.96	
— " 18	17	14 0	.4	.72	28.22	
— " 20	6	17	.4	.75	.25	
— " 22	35 58	38	.0	.79	.36	
IV. 1. 0	52	15 0	.1	.79	.34	
— " 2	46	10	.3	.72	.24	
— " 4	40	41	.2	.81	.33	
— " 6	32	58	.2	.79	.32	
— " 8	15	16 20	.5	38.26	.62	
— " 10	19	40	.5	.28	.63	
— " 12	15	58	.5	.17	.54	
— " 14	8	17 20	.7	.21	.53	
— " 16	1	24	15.0	.21	.46	
— " 18	3	33	.1	.24	.46	
— " 20	34 56	56	14.9	.22	.50	
— " 22	51	18 14	.8	.28	.56	
— 2. 0	44	34	.4	.31	.68	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Density	
1929	° '	° '	°C.	‰	σ_t	
IV. 2. 2	34 38	18 54	14.6	38.40	28.70	Mediterranean Sea.
— " 4	33	19 14	.2	.31	.72	
— " 6	27	31	.4	.42	.76	
— " 8	19	47	.3	.49	.84	
— " 10	15	20 5	15.4	.48	.58	
— " 12	11	24	.2	.46	.61	
— " 14	6	42	.3	.55	.66	
— " 16	33 59	21 2	.7	.39	.44	
— " 18	58	7	—	.37	—	
— " 20	57	23	.4	.37	.49	
— " 22	52	42	.0	.58	.75	
— 3. 0	46	22 0	.1	.53	.68	
— " 2	41	18	.3	.31	.47	
— " 4	35	36	.5	.06	.24	
— " 6	30	23 7	.5	.39	.49	
— " 8	25	22	.6	.49	.55	
— " 10	21	36	.5	.51	.58	
— " 12	16	50	.4	.51	.60	
— " 14	10	24 9	.8	.58	.57	
— " 16	6	28	.8	.66	.63	
— " 20	1	54	.4	.64	.70	
— " 22	32 55	25 13	.9	.44	.43	
— 4. 0	48	31	.6	.57	.60	
— " 2	42	48	16.0	.73	.64	
— " 4	36	26 4	15.8	.49	.50	
— " 6	32	22	.9	.48	.46	
— " 8	30	26	16.0	.57	.50	
— " 10	22	39	.1	.62	.53	
— " 12	13	51	.1	.40	.36	
— " 14	12	58	.3	.96	.75	
— " 16	9	27 10	.2	.87	.70	
— " 18	11	38	.2	.71	.57	
— " 20	3	44	.1	.49	.43	
— " 22	31 56	28 3	.0	.48	.44	
— 5. 0	50	21	15.8	.44	.46	
— " 2	46	32	16.1	.58	.50	
— " 4	43	42	.1	.46	.41	
— " 6	29	29 5	.1	.46	.41	
— " 8	23	31	.3	.49	.39	
IV. 12. 20	29 51	32 33	19.1	42.35	30.64	Red Sea.
— " 22	34	33	17.9	.21	.85	
— 13. 0	19	40	.7	.12	.82	
— " 2	5	46	.6	41.85	.65	
— " 4	28 50	53	.9	.85	.57	
— " 6	34	33 1	18.2	.59	.28	
— " 8	37	11	.6	.53	.14	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Density	
1929	° '	° '	°C.	‰	σ _t	
IV. 13. 10	28 17	33 23	19.7	41.22	29.61	Red Sea.
— " 12	27 57	35	22.6	40.73	28.43	
— " 14	47	47	24.1	.57	27.85	
— " 16	36	59	23.7	.52	.93	
— " 18	20	34 12	24.2	.46	.74	
— " 20	10	19	23.7	.53	.94	
— " 22	26 55	30	22.2	.53	28.38	
— 14. 0	41	39	.5	.41	.20	
— " 2	27	48	23.3	39.97	27.64	
— " 4	15	57	.4	40.26	.83	
— " 6	0	35 8	.3	.25	.84	
— " 8	25 48	16	.9	.23	.65	
— " 10	35	26	24.2	.43	.71	
— " 12	23	35	.5	.28	.51	
— " 14	7	46	.8	.26	.41	
— " 16	24 52	56	25.8	39.79	26.74	
— " 18	38	36 5	.6	.97	.93	
— " 20	23	15	24.9	.99	27.17	
— " 22	8	24	25.5	.29	26.45	
— 15. 0	23 53	34	.4	.65	.75	
— " 2	39	43	26.3	—	—	
— " 4	24	53	.4	.14	.05	
— " 6	10	37 2	25.7	.90	.85	
— " 8	22 59	9	.8	.88	.81	
— " 12	43	21	26.9	.61	.25	
— " 14	29	29	27.7	38.93	25.47	
— " 16	23	33	.3	39.38	.94	
— " 18	12	40	.0	.42	26.07	
— " 20	21 56	48	.2	.13	25.79	
— " 22	42	57	.1	38.51	.35	
— 16. 0	27	38 6	.3	.95	.62	
— " 2	13	16	28.0	.42	.00	
— " 4	0	24	.8	.28	24.61	
— " 6	20 46	33	.5	.42	.83	
— " 8	33	41	27.5	.93	25.54	
— " 10	18	50	28.4	.87	.20	
— " 12	2	39 0	29.0	.40	24.64	
— " 14	19 48	9	.1	.15	.42	
— " 18	35	18	.1	.30	.53	
— " 20	24	28	.2	.03	.29	
— " 22	10	36	.0	.37	.61	
— 17. 0	18 56	45	28.3	37.75	.39	
— " 2	42	53	.1	.59	.34	
— " 4	30	40 1	.2	.65	.34	
— " 6	17	9	.0	.77	.50	
— " 8	1	26	.0	.77	.50	
— " 10	17 50	58	.7	.75	.26	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Density	
1929	° ' "	° ' "	°C.	‰	σ_t	
IV. 17. 12	17 38	40 39	28.4	37.19	23.94	Red Sea.
— " 14	23	39	.6	.25	.91	
— " 16	19	41	.3	.05	.86	
— " 18	5	48	.1	.52	24.28	
— " 20	16 54	52	27.2	.99	.93	
— " 22	40	41 1	.1	38.15	25.08	
— 18. 0	27	10	.1	37.48	24.58	
— " 2	16	20	26.7	.75	.91	
— " 4	5	31	.2	.21	.66	
— " 6	15 54	43	.5	.23	.58	
— " 8	50	49	.5	.07	.45	
— " 10	47	44	.7	.01	.35	
— " 12	47	44	.7	.09	.41	
— " 14	43	37	.8	.12	.40	
— " 16	43	50	.9	36.96	.25	
— " 18	39	41	.4	37.05	.47	
— " 20	28	50	.4	36.64	.17	
— " 22	16	57	.3	.92	.41	
— 19. 0	5	42 3	.4	.53	.08	
— " 2	14 52	12	.6	.96	.35	Gulf of Aden.
— " 4	40	20	.5	.91	.33	
— " 6	24	31	.6	—	—	
IV. 23. 8	12 40	45 0	28.1	—	—	
— " 20	32	46 17	.1	.31	.36	
— 24. 0	29	50	27.6	.31	.53	
— " 4	25	47 23	.6	.18	.44	
— " 8	18	48 19	28.1	.38	.42	
— " 12	14	43	29.0	.11	22.92	
— " 16	11	49 16	.1	.31	23.03	
— " 20	8	47	28.4	35.77	22.87	Indian Ocean.
— 25. 0	3	50 21	.4	36.27	23.24	
— " 4	0	51 2	27.9	.42	.51	
— " 8	11 55	28	28.4	.02	.05	
— " 12	19	53	30.5	.04	22.35	
— " 16	10 56	52 18	.6	.17	.42	
— " 20	35	39	28.3	.02	23.09	
— 26. 0	13	53 0	27.9	35.95	.16	
— " 4	9 52	22	28.0	36.06	.21	
— " 8	33	41	.9	35.93	22.82	
— " 12	8	54	29.3	.75	.55	
— " 16	8 45	54 14	.8	.75	.38	
— " 20	23	33	28.6	.52	.61	
— 27. 0	2	54	.9	—	—	
— " 4	7 40	55 17	29.0	.05	.12	
— " 8	42	41	.4	.03	21.97	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Density	
1929	° ' "	° ' "	°C.	‰	σ_t	
IV. 27. 12	7 39	55 43	30.0	35.05	21.78	Indian Ocean.
— " 16	32	54	.0	.07	.80	
— " 20	27	56 23	29.3	34.88	.89	
— 28. 0	14	51	.2	35.25	22.20	
— " 4	0	57 20	.1	.26	.25	
— " 8	6 41	53	.1	.26	.25	
— " 12	23	58 26	.4	.32	.19	
— " 16	8	56	.1	34.96	.02	
— " 20	5 42	59 19	.1	.94	.01	
— 29. 0	37	47	.1	.85	21.93	
— " 4	23	60 15	.2	.27	.47	
— " 8	4 59	53	.5	.31	.40	
— " 12	37	61 31	.7	.29	.31	
— " 16	23	62 1	.5	.70	.70	
— " 20	14	31	.1	.94	22.01	
— 30. 0	4	63 2	.0	.81	21.95	
— " 4	3 54	34	28.8	.78	.99	
— " 8	49	42	29.1	.72	.84	
— " 12	48	49	.0	.67	.84	
— " 16	42	64 9	.1	.52	.69	
— " 20	28	35	28.8	.60	.85	
V. 1. 0	18	65 6	.8	.58	.84	
— " 4	8	38	.1	.70	22.16	
— " 8	2 51	55	.8	.83	.03	
— " 12	35	66 38	29.0	.99	.08	
— " 16	—	—	28.8	—	—	
— " 20	14	67 37	.4	.87	.19	
— 2. 0	1	68 9	.4	35.03	.31	
— " 4	1 54	41	.2	34.81	.21	
— " 8	45	69 17	.4	35.16	.40	
— " 12	36	51	.8	.16	.27	
— " 16	30	70 23	.8	.16	.27	
— " 20	24	53	.4	.07	.34	
— 3. 0	18	71 25	.4	34.78	.12	
— " 4	11	56	.5	35.14	.36	
— " 8	3	72 44	.6	.19	.36	
— 4. 16	0 44	73 26	.6	.17	.35	
— " 20	37	53	.5	.03	.27	
— 5. 0	29	74 23	.3	.14	.42	
— " 4	21	53	.3	34.99	.31	
— " 8	21	75 43	.3	35.19	.46	
— " 12	17	76 27	.7	.32	.42	
— " 16	9	58	.5	.26	.45	
— " 20	5	77 46	.4	.26	.49	
	Lat. S.					
— 6. 0	4	78 17	.2	.19	.49	
— " 4	12	79 46	.5	.12	.34	

Table I. Surface-observations.

Date. Hour. (Ship's Time)	Position		Sea-Surface			Remarks
	Lat. S.	Long. E.	Temp.	Salinity	Density	
1929	° ' "	° ' "	°C.	‰	σ_t	
V. 6. 16	0 10	80 7	28.7	35.30	22.41	Indian Ocean.
— " 20	22	47	.4	.30	.51	
— 7. 0	33	81 16	.6	.30	.45	
— " 4	44	44	.4	.23	.46	
— " 8	47	82 32	.4	.10	.36	
— " 12	56	83 15	.7	.21	.35	
— " 16	1 4	46	.5	.23	.42	
— " 20	10	84 27	.6	34.87	.12	
— 8. 0	7	58	.5	35.08	.31	
— " 4	6	85 31	.4	34.79	.13	
— " 8	11	86 25	.7	.94	.14	
— " 12	10	87 9	29.0	.94	.04	
— " 16	6	42	28.8	.79	.00	
— " 20	5	88 27	.5	.96	.22	
— 9. 0	1 1	89 2	.6	.74	.03	
— " 4	0 57	32	.7	.74	21.99	
— " 8	1 4	90 36	.9	.99	22.11	
— " 12	7	91 25	.4	.99	.28	
— " 16	3	58	.8	.72	21.94	
— " 20	8	92 48	.7	.51	.82	
— 10. 0	2	93 19	.7	.69	.95	
— " 4	0 57	50	.6	.76	22.04	

TABLE II. SERIAL OBSERVATIONS AT THE STATIONS.

Stat. 9. 14. March 1929. Atlantic Ocean. 44° 9' N. 9° 9' W. 2210 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Sanility ‰	Oxygen cc/l	Density σ_t
10.40	I	0	12.8	35.66	—	26.96
		96	.06	.65	—	27.10
		192	11.99	.59	—	.06
		384	.09	.54	—	.20 ^s
		960	10.31	.90	—	.62
		1152	9.94	.90	—	.68
		1536	6.38	.33	—	.78
		2180	3.85	.98	—	28.60 ^s
10.00	Bottom					

Table II. Serial observations at the stations.

Stat. 10. 29. March 1929. Mediterranean Sea. 37° 12' N. 6° 55' E. 2245 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ_t
15.48	I	0	13.5	37.00	—	27.85
		98	.65	.97	—	28.57
		197	.24	38.30	—	.92
		295	.29	.43	—	29.00 ^s
		393	.23*	.51	—	.08
		590	.09	.50	—	.10 ^s
		885	12.96	.45	—	.09
14.45	Bottom	2215	13.02	.41	—	.05
Stat. 11. 31. March 1929. Mediterranean Sea. 36° 38' N. 12° 56' E. 1069 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ_t
11.11	I	0	13.8	37.43	—	28.13
		99	.66	.57	—	.26
		198	14.36	38.20	—	.59 ^s
		297	.45	.76	—	29.00 ^s
		397	.09	.77	—	.09
		595	13.97	.71	—	.08
		892	.95	.72	—	.09
10.30	Bottom	1039	.95	.71	—	.08
Stat. 12. 1. April 1929. Mediterranean Sea. 35° 13' N. 17° 0' E. 3217 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ_t
16.19	I	0	15.1	38.20	—	28.42 ^s
		99	14.35	.30	—	.68
		198	15.00	.75	—	.88
		297	14.70	.82	—	29.00
		397	.35	.78	—	.05
		595	13.95	.82	—	.17
		892	.68	.73	—	.16
15.30	Bottom	3187	.72	.53	—	28.99

*) Interpolated from curve.

Table II. Serial observations at the stations.

Stat. 13. 2. April 1929. Mediterranean Sea. 33° 59' N. 21° 15' E. 2520 metres.								
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t		
17.05	I	0	15.7	38.39	—	28.44		
		100	.14	.45	—	.62		
		200	14.85	.77	—	.92		
		300	.72	.80	—	.98		
		400	.24	.78	—	29.08		
		600	13.80	.73	—	.13		
		900	.61	.67	—	.12 ^s		
Stat. 14. 3. April 1929. Mediterranean Sea. 33° 6' N. 24° 28' E.								
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t		
16.47	I	0	15.8	38.66	—	28.63		
		500	13.79	.73	—	29.13		
		1000	.55	.66	—	.13		
		1500	.54	.65	—	.12		
		1950	.56	.67	—	.12 ^s		
Stat. 16. 15. April 1929. Red Sea. 22° 57' N. 37° 12' E. 1097 metres.								
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t		
8.35	I	0	25.8	39.88	—	26.80		
		25	.18	.85	4.52	.97		
		50	24.55	.89	.53	27.19 ^s		
		100	.60	40.01	.23	.27		
		150	.48	.13	.04	.39 ^s		
		250	23.02	.32	—	.98		
		9.25	II	400	21.69	.54	2.37	28.54
				500	.61	.59	1.82	.60
600	.61			.55	.91	.57		
8.00	Bottom	700	.60	.56	2.03	.57 ^s		
		900	.61	.57	.35	.58		
		1067	.64	.50	—	.52		

Table II. Serial observations at the stations.

Stat. 17. 16. April 1929. Red Sea. 19° 48' N. 39° 9' E. 493 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
16.01	I	0	29.1	38.15	—	24.42
		25	27.13	.17	4.46	25.08
		50	26.62	.27	.48	.32 ^s
		100	25.29	39.40	3.75	26.60
		150	22.55	40.23	.66	28.05
15.03	II	200	21.92	.28	1.22	.27
		250	.73	.27*	0.67	.32 ^s
		300	.66	.25	.67	.32
		350	.62	.23	.54	.32
		400	.59	.16	.68	.27
14.25	Bottom	463	.59	.41	.89	.46
Stat. 18. 18. April 1929. Red Sea. 15° 52' N. 41° 43' E. 1031 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
11.15	I	0	26.7	37.07	—	24.39
		25	.10	.11	3.41	.61
		50	25.99	.42	.45	.88
		100	22.51	40.27	1.89	28.09 ^s
		150	21.94	.46	.60	.41
11.49	II	250	.66	.57	0.94	.57
		400	.57	.59	1.04	.61
		500	.57	.61	.18	.62
		600	.58	.57	.55	.59
		700	.60	.60	.61	.60 ^s
10.45	Bottom	900	.63	.60*	—	.59 ^s
		1001	.66	.60	.87	.58 ^s
Stat. 19. 19. April 1929. Red Sea. 13° 27' N. 42° 51' E. 165 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
16.35	I	0	27.6	36.12	—	23.39
		10	.53	.22	4.29	.48
		25	.41	.33	.35	.61
		50	.28	.36	.31	.68
		75	26.55	.88	3.71	24.29
		100	24.53	38.57	.04	26.20
		125	22.80	39.98	2.08	27.79
16.10	Bottom	135	.80	—	—	—

*) Interpolated from curve.

Table II. Serial observations at the stations.

Stat. 20. 24. April 1929. Gulf of Aden. 12° 35' N. 45° 48' E.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
15.17	I	0	28.8	36.25	—	23.08
		50	25.36	.05	4.64	24.04
		100	22.70	35.87	2.77	.69 ^b
		150	18.12	.52	0.94	25.65
		250	14.76	.45	.61	26.39
		350	.84	36.00	.66	.80
15.58	II	500	.89	.36	.68	27.07
		700	13.50	.24	.59	.26
		900	12.51	.22	.50	.45
		1100	10.26	35.88	.39	.61
Stat. 21. 27. April 1929. Indian Ocean. 7° 38' N. 55° 43' E. 4734 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
10.05	I	0	29.82	34.90	—	21.74
		25	.56	.97	4.46	.88
		50	28.28	35.32	.53	22.56
		100	24.50	.48	3.71	23.87
		150	19.81	.44	2.25	25.16
		200	15.22	.25	.46	26.13
		300	12.68	.21	.03	.14
		500	9.82	.08	1.78	27.06
11.02	II	750	.85	.32	0.61	.24
		1000	7.92	.23	0.75	.48
		1500	5.17	34.97	1.55	.66
		2000	2.76	.79	.62	.76
12.37	III	3000	1.92	.76	3.18	.80
		4000	.44	.73	4.04	.82

Table II. Serial observations at the stations.

Stat. 22. 30. April 1929. Indian Ocean. 3° 48' N. 63° 48' E. 4061 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
10.11	I	0	29.1	34.73	—	21.85
		25	.14	.82	4.31	.90 ^s
		50	26.32	35.50	3.57	23.33
		100	20.41	.37	1.67	24.96
		150	16.12	.21	.43	25.90
		200	13.86	.16	.34	26.35
		300	12.12	.13	2.09	.68
		500	10.20*	.12	1.29	27.03
11.25	II	750	8.70	.14	0.72	.29
		1000	6.97	.05	0.91	.48
		1500	4.51	34.90	1.74	.68
		2500	2.10	.81	3.15	.84
		3500	1.93	.74	.15	.79
Stat. 23. 6. May 1929. Indian Ocean. 0° 5' S. 79° 46' E. 4671 metres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ _t
10.21	I	0	28.62	35.27	—	22.41 ^s
		25	.69	.25	4.35	.37
		50	.67	.26	.37	.39
		100	27.83	.29	.13	.69
		150	20.85	.35	2.89	24.82
		200	15.44	.23	1.78	26.07
		300	13.27	.12	2.04	.45
		500	11.03	.03	1.84	.81
11.45	II	750	8.33	.01	.00	27.26
		1000	6.68	34.94	.11	.44
		1500	4.84	.59	—	.38 ^s
		2000	3.06	.76	—	.71
		3000	1.85	.68	3.08	.74 ^s
		4000	.39	.60	.71	.71
8.40	Bottom	4641	.41	.71	—	.80 ^s

*) Interpolated from curve.

Table II. Serial observations at the stations.

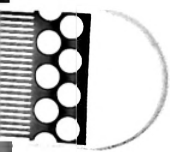
Stat. 24. 10. May 1929. Indian Ocean. 1° 6' S. 94° 53' E. 4748 mètres.						
Ship's Time	Serial Nr.	Depth m	Temp. °C.	Salinity ‰	Oxygen cc/l	Density σ_t
11.45	I	0	28.6	34.76	—	22.03
		25	.76	.75	4.15	21.97 ^s
		50	.78	.79	.20	22.00
		100	.85	.85	.06	.02
		150	.26	.88	3.87	.24
		200	19.63	35.09	2.14	24.95
		300	15.02	.09	1.37	26.06
		500	10.90	34.96	.55	.78
		750	8.36	.96	.03	27.20
13.12	II	1000	6.80*	.92	.07	.40
		1500	4.34	.55	.93	.41 ^s
		2000	2.80	.70	2.73	.69
		3000	1.72	.70	3.36	.78
		4000	.17	.70	4.13	.82
		4718	.18	.71	3.98	.82 ^s
8.35	Bottom	4718	.18	.71	3.98	.82 ^s

*) Interpolated from curve.

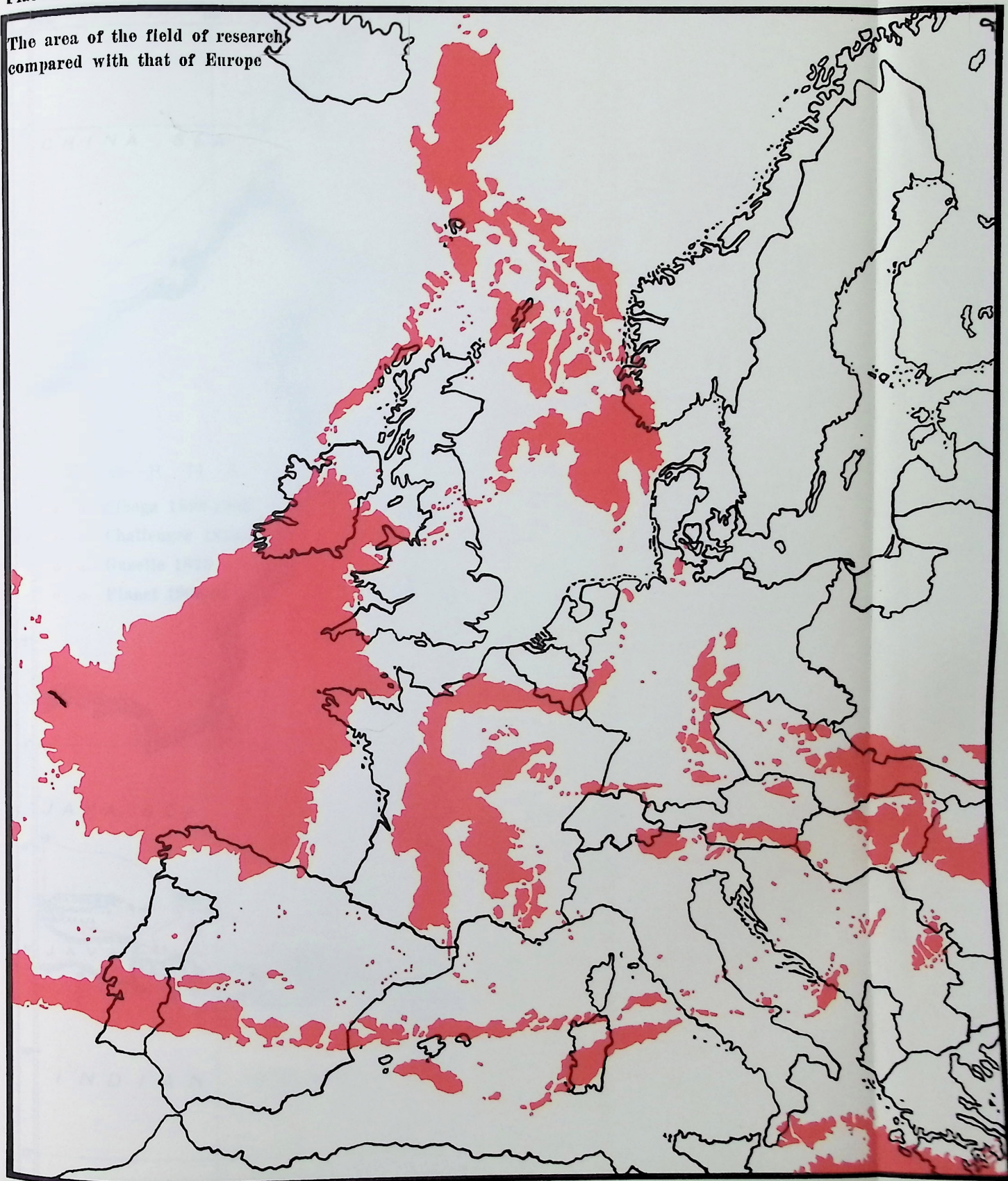
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PLATES I—IX

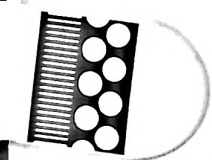


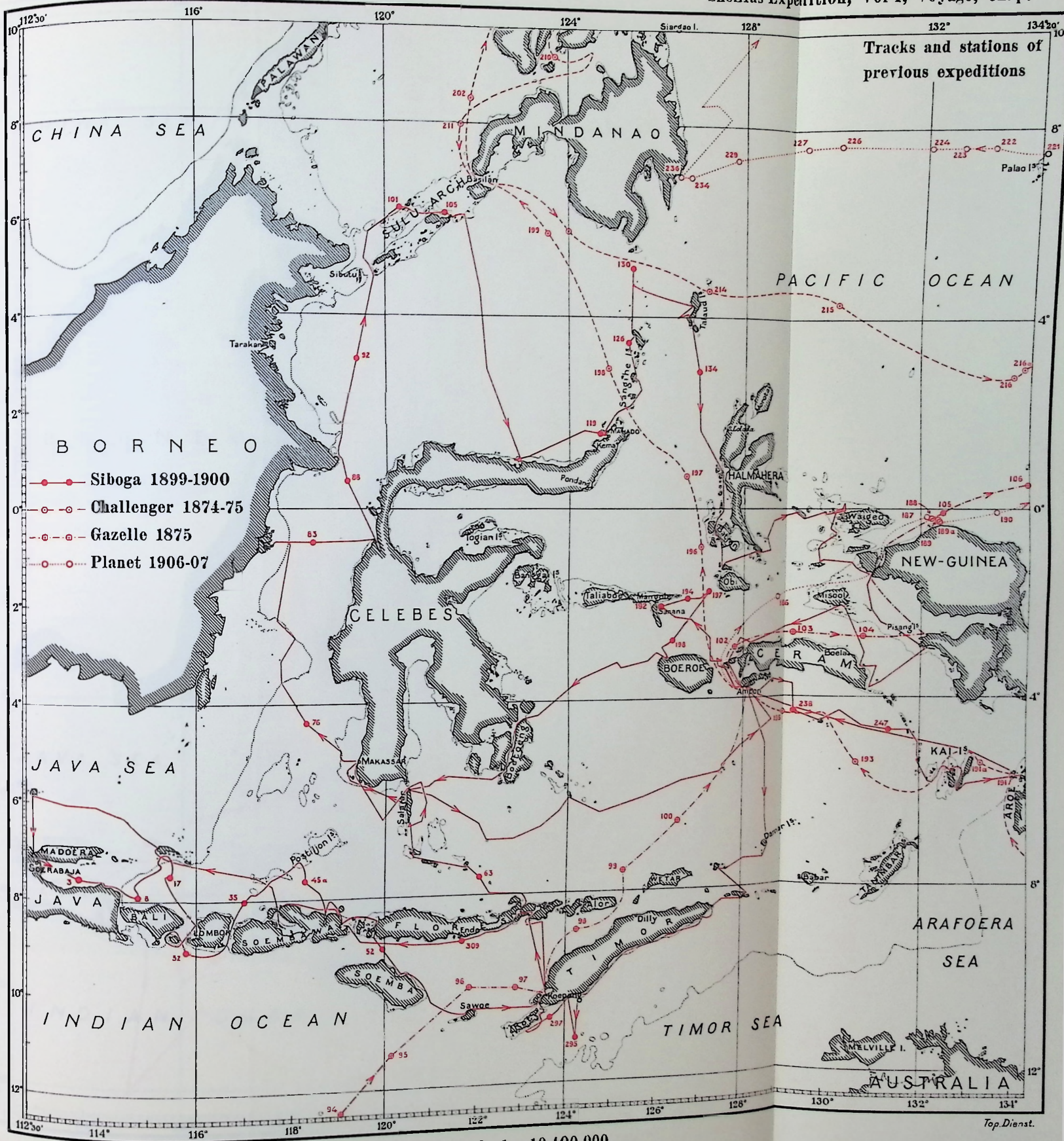
The area of the field of research
compared with that of Europe



Scale 1 : 15.000.000

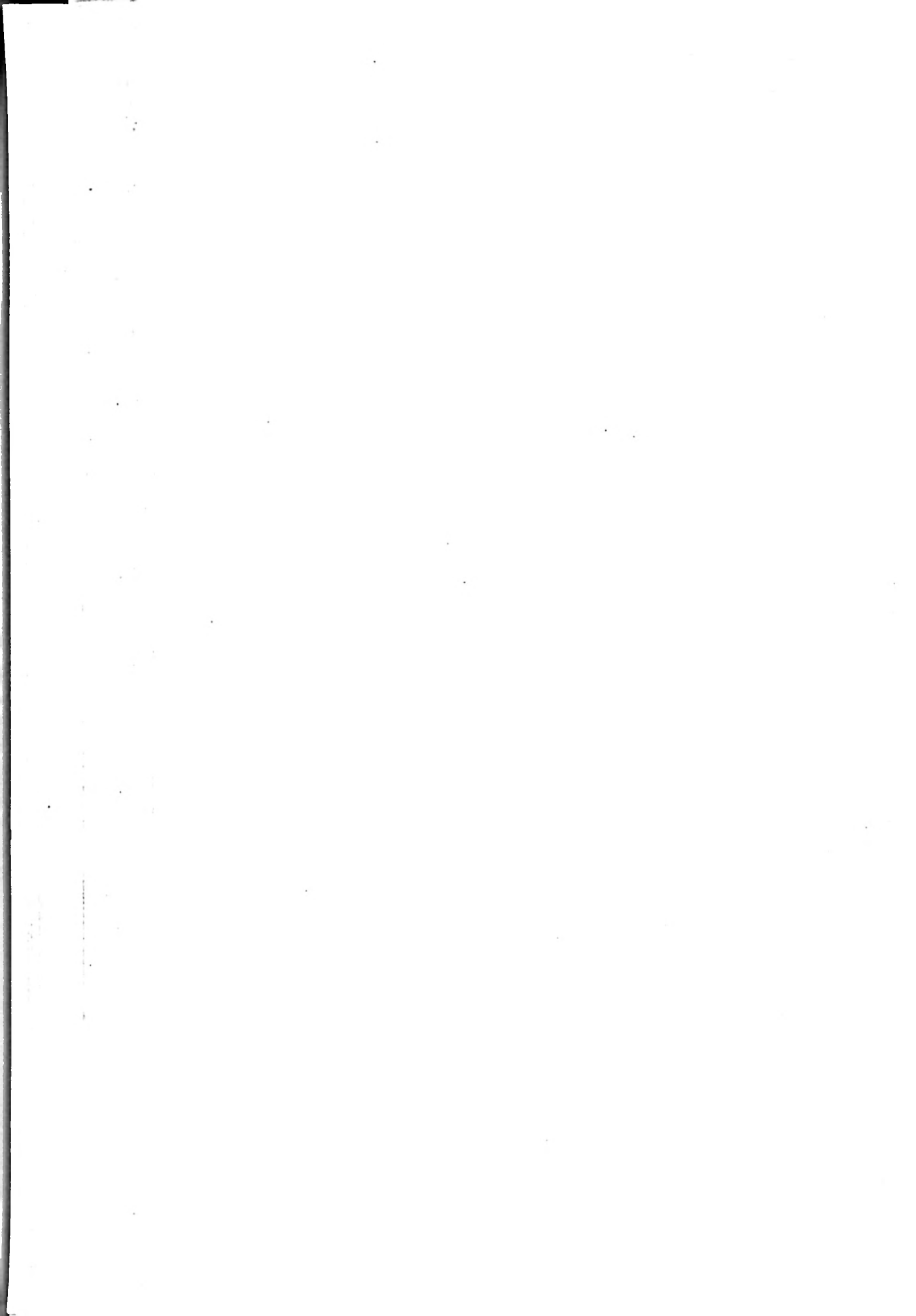
Dr. Dierckx



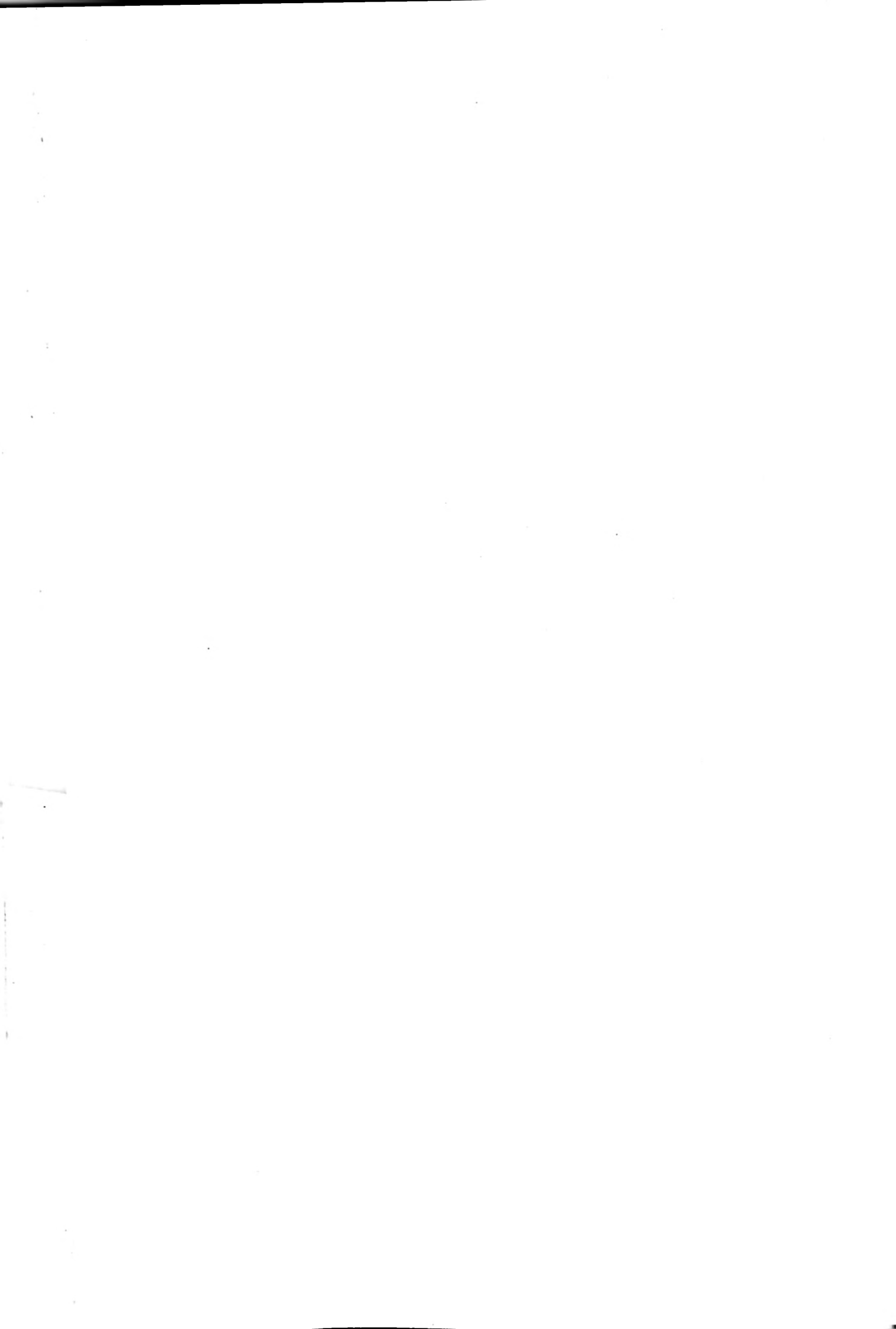


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Top. Dienst.







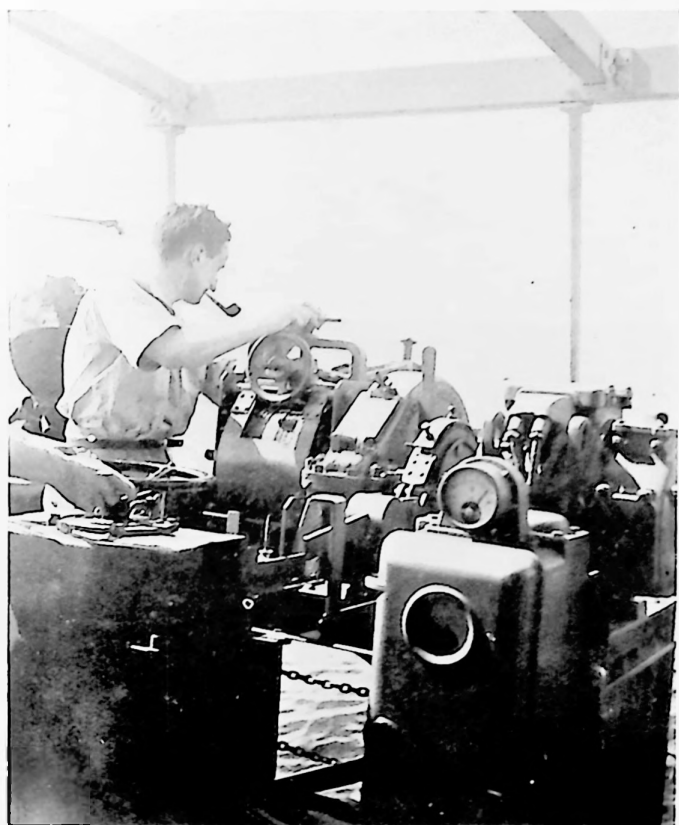


Fig. 1. Dr. Hardon at the Lucas sounding machine.



Fig. 2. Ekman bottom sampler.

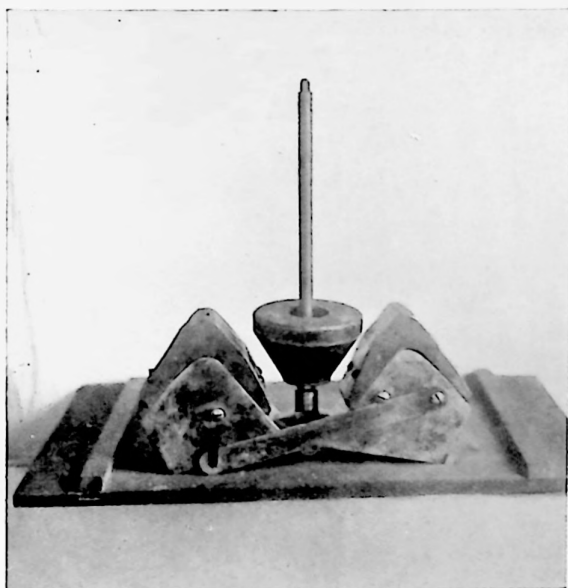


Fig. 3. Monaco sampler with additional weight.

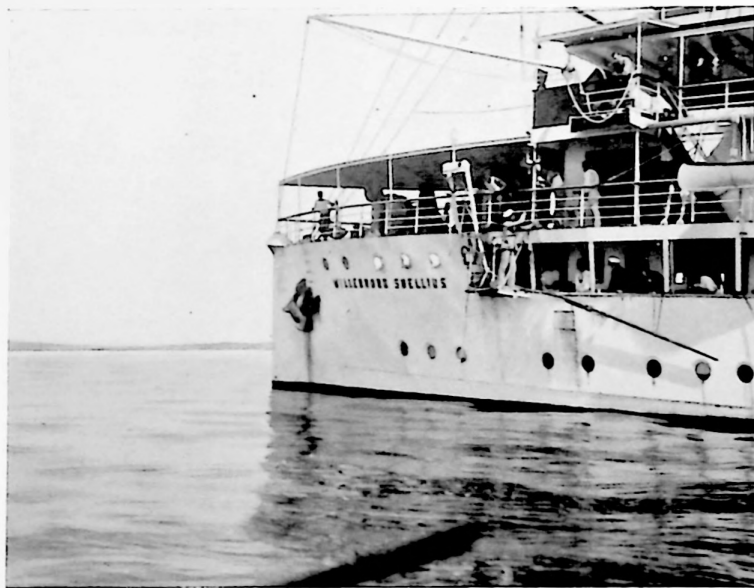


Fig. 4. Heavy bottom sampler. Length 4 metres.

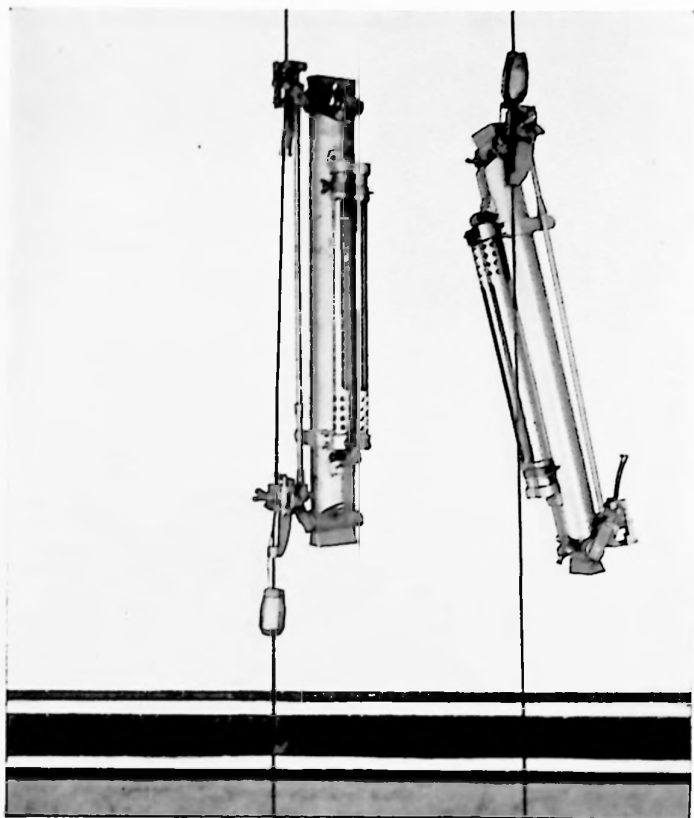


Fig. 1. Nansen water bottle improved by Marx & Berndt.
left: lowered, open; right: hauled in, closed.



Fig. 5 The serial winch.

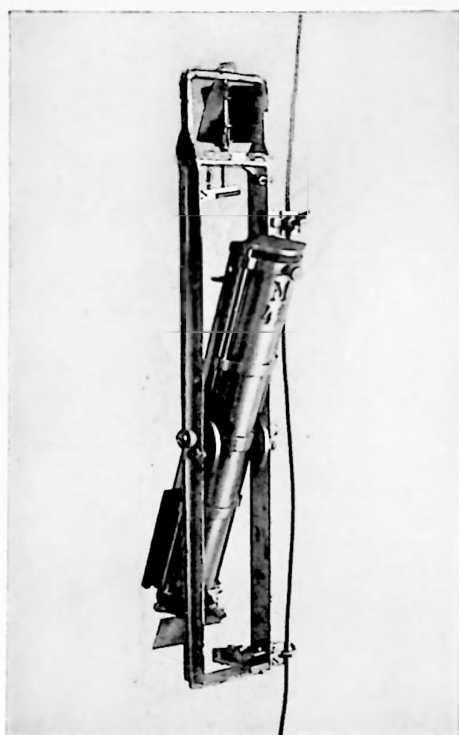


Fig. 4. Bottom water bottle
(Marx & Berndt).

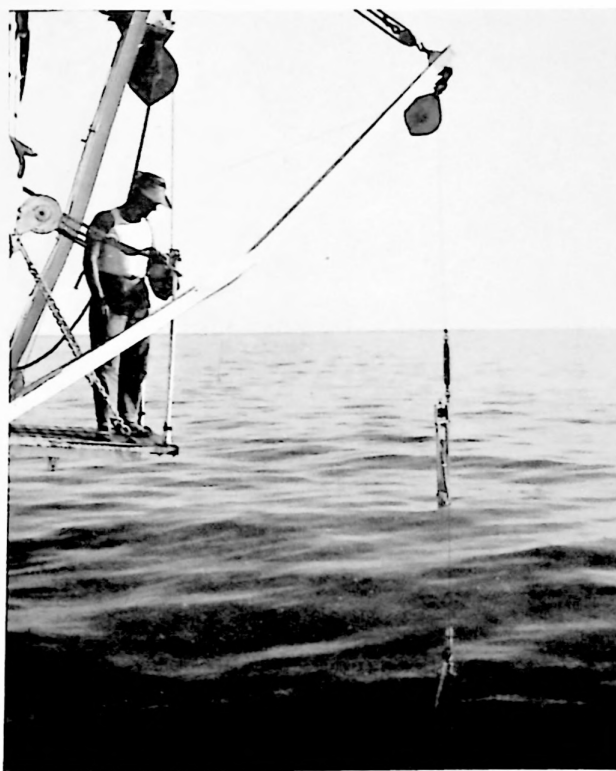


Fig. 2. Oceanographic instruments for bottom water
observations, attached above the bottom sampler.



Fig. 3.
Reversing
thermometer
(Richter & Wiese).





Fig. 1. Drawing samples from the water bottles for chemical determinations.



Fig. 2. A corner in the chemical laboratory.

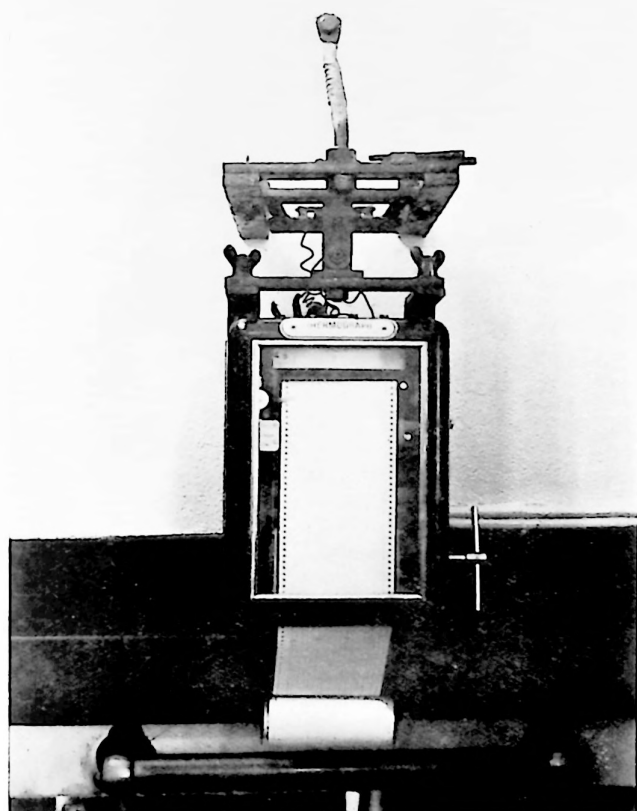


Fig. 3. Thermograph for registering surface temperature.

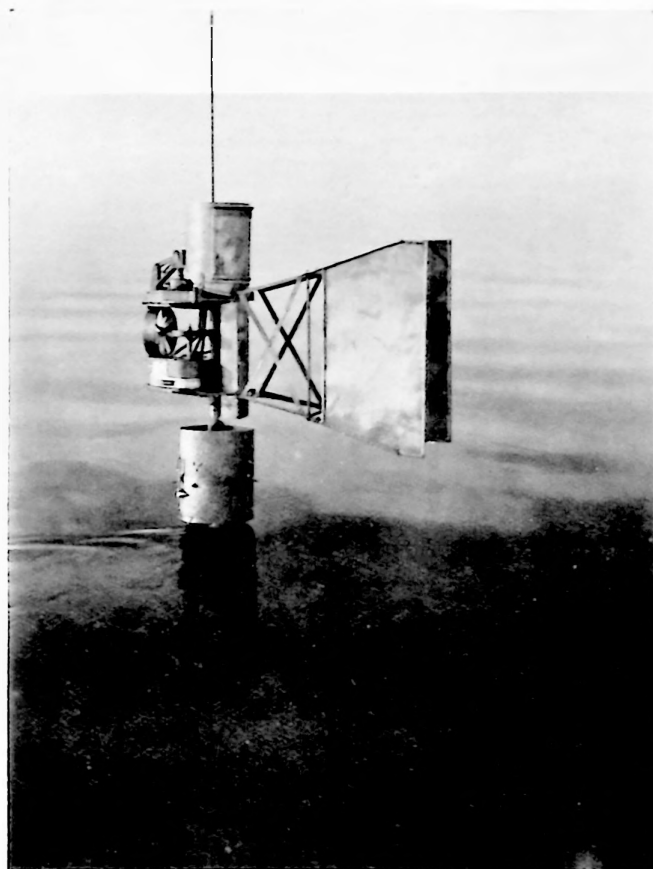


Fig. 4. Ekman repeating current-meter.



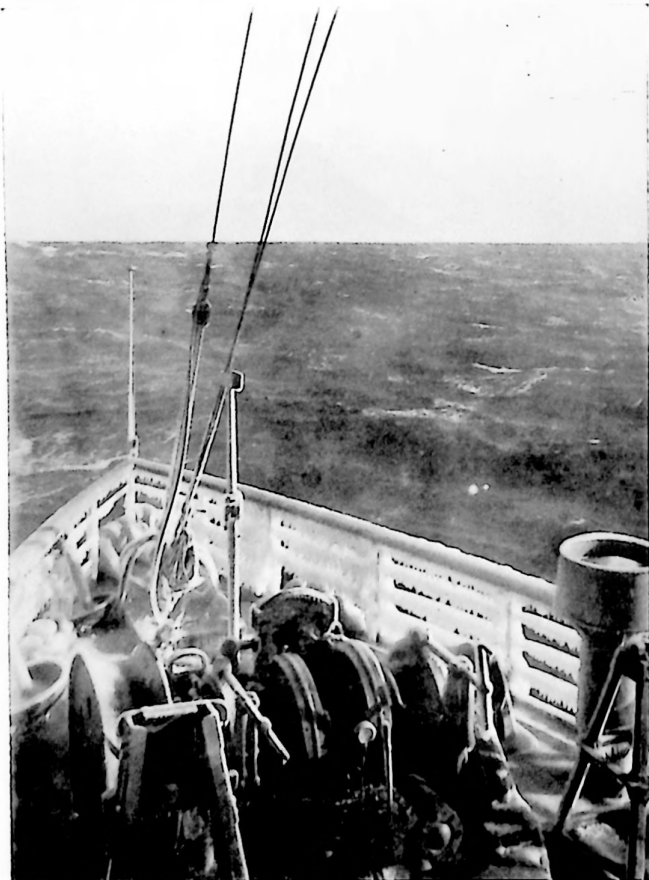


Fig. 1. Ice formed from waves breaking over the fore-castle.



Fig. 2. The "Snellius" struggling with floating ice in the harbour of Den Helder.



Fig. 4. Algiers.



Fig. 3. Vice-Admiral L. J. Quant addressing a word of parting.





Fig. 1. Part of the crew visiting Cairo.



Fig. 2. Medical officer Broekhoff, Prof. Boschma and Lieutenant van Straelen.
The first hot day after leaving Suez.

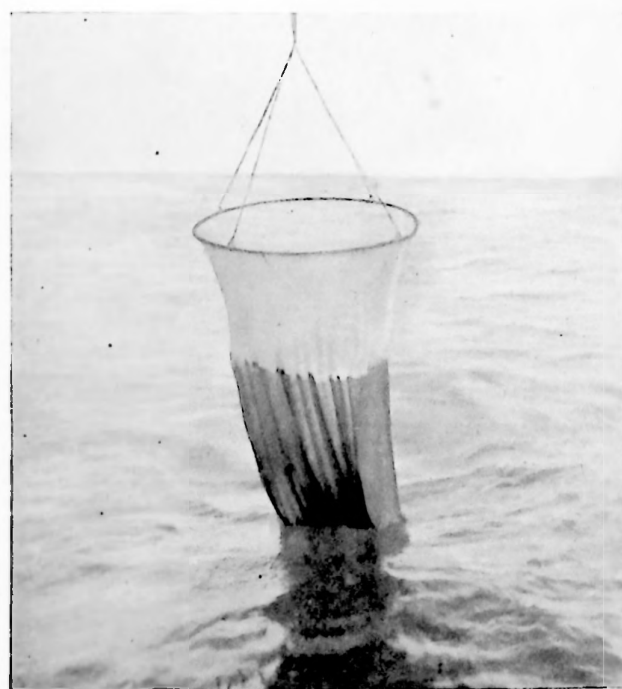


Fig. 3. The large plankton net.

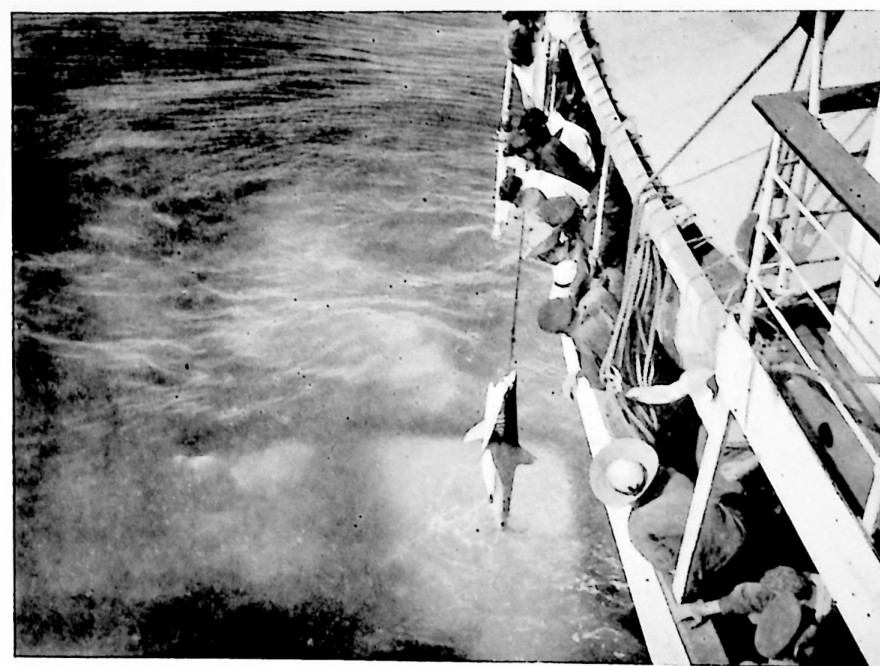


Fig. 4. The first shark.





Fig. 1. Aden.



Fig. 2. Maldives. Suvadiva atoll.



Fig. 3. Mrs. van Riel and Commander Pinke taking a walk at Suvadiva.



Fig. 4. Neptune shaving our medical officer.

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN
P. M. VAN RIEL

DIRECTEUR VAN DE FILIAALINRICHTING VAN HET KONINKLIJK
NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË
AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN
F. PINKE

LUITENANT TER ZEE DER 1^e KLASSE

1929–1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET
NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN
HET KONINKLIJK NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP



GEDRUKT DOOR EN TE VERKRIJGEN BIJ

E. J. BRILL — LEIDEN



H. M. S. „Willebrord Snellius”.

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE



VOL. I

VOYAGE

CHAPTER II

THE EXPEDITIONARY SHIP AND THE NAVAL PERSONNEL'S SHARE

BY

F. PINKE
LIEUTENANT COMMANDER ROYAL DUTCH
NAVY, COMMANDING H.M.S. „WILLEBRORD SNELLIUS”

WITH APPENDIX 3

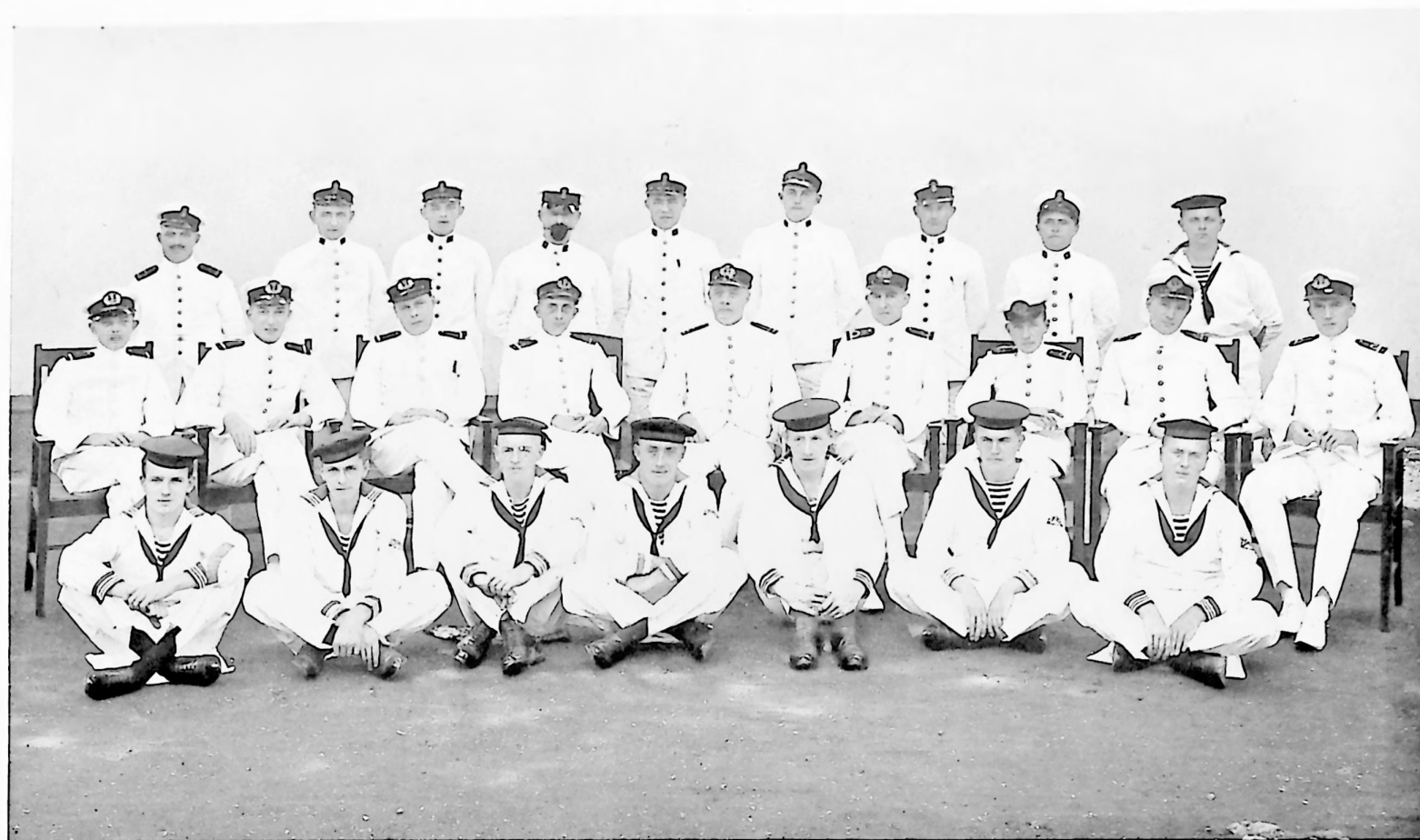
THE DEEP-SEA ANCHORAGE EQUIPMENT

BY

J. P. H. PERKS
SENIOR OFFICER

1938

TO BE OBTAINED OF THE PRINTERS AND PUBLISHERS
E. J. BRILL - LEIDEN



Most of the officers, warrant officers and European crew who took part in the Expedition.

Upper row, from left to right: Mallie, Snabel, Worrell, Wallast, Woltering, Van Haasteren, Kabel, Kater, Van Kapel.

Middle row, from left to right: Bakker, Broekhoff, Staverman, Vos, Pinke, Perks, Milo, Van Straelen, Veldman.

Undermost row, from left to right: Geljon, Louws, Groters, Woltering, Onkenhout, Wassenaar, Stolk.

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CHAPTER 1

1.1. Introduction. The purpose of this chapter is to introduce the reader to the basic concepts and terminology of the theory of functions of a complex variable. We shall begin by discussing the complex plane and the complex-valued functions defined on it. We shall then discuss the concept of a limit and the definition of a function being analytic at a point. We shall then discuss the concept of a contour integral and the Cauchy theorem. Finally, we shall discuss the concept of a power series and the concept of a function being analytic in a domain.

1.2. The complex plane. The complex plane is the set of all complex numbers, which can be represented as points in a two-dimensional plane. The horizontal axis is the real axis and the vertical axis is the imaginary axis. The origin is the point where the two axes intersect. A complex number z is represented by the point (x, y) in the plane, where x is the real part and y is the imaginary part. The complex plane is denoted by \mathbb{C} .

1.3. Complex-valued functions. A complex-valued function is a function that maps a set of complex numbers to a set of complex numbers. If z is a complex number, then $f(z)$ is a complex number. The domain of a function is the set of all complex numbers z for which $f(z)$ is defined. The range of a function is the set of all complex numbers w such that $w = f(z)$ for some z in the domain.

1.4. Limits and analytic functions. A function $f(z)$ is said to have a limit L as z approaches a point a if, for every $\epsilon > 0$, there is a $\delta > 0$ such that $|f(z) - L| < \epsilon$ whenever $|z - a| < \delta$. A function $f(z)$ is said to be analytic at a point a if it has a unique power series expansion in a neighborhood of a . A function $f(z)$ is said to be analytic in a domain D if it is analytic at every point in D .

1.5. Contour integrals and the Cauchy theorem. A contour integral is an integral of a complex-valued function over a path in the complex plane. If γ is a contour in the complex plane, then the contour integral of $f(z)$ over γ is denoted by $\int_{\gamma} f(z) dz$. The Cauchy theorem states that if $f(z)$ is analytic in a domain D and γ is a closed contour in D , then $\int_{\gamma} f(z) dz = 0$.

1.6. Power series and analytic functions. A power series is a series of the form $\sum_{n=0}^{\infty} a_n (z - a)^n$, where a_n are complex numbers and a is a complex number. A function $f(z)$ is said to be analytic in a domain D if it can be represented by a power series in a neighborhood of every point in D .

CHAPTER II

A. FITTING OUT THE SHIP

At the end of October 1927 I was informed of the intention to submit a proposal to the Queen to place me in command of H.M.S. „Willebrord Snellius”. After being attached for a few months with the Observatory at Utrecht, I was able to devote all my time to the fitting out of the ship and preparing for the expedition. At the end of January 1929 the „Willebrord Snellius” was commissioned.

Ten months seems to be a rather long time for the preparations, and yet it is very short. On a rarely occurring and costly expedition all the time available has to be utilised as far as possible in making the scientific surveys and explorations, with the minimum loss of time in experimenting and practising. Consequently when making the preparations it is necessary to take into account already every detail of the work that has to be done, so that right from the outset every instrument is given its right place and every person is fully instructed in the duties he will have to perform. Well begun is half done!

If one is inexperienced in this special kind of work it is of much value to have information from someone who has that experience. In a circular (November 1927) from the commission for the technical and financial preparations it is stated that „in Holland deep-sea exploration is not on such a high level as may be expected of a people renowned of old as a seafaring and scientifically advanced nation”. And indeed there were but few people in Holland who had made a study of oceanography, and still fewer with practical experience in that science. The Siboga-expedition dated back 30 years, the physical-oceanographic research held a less prominent position at that time than would be the case in this expedition, and moreover since that time new instruments and apparatuses had been invented. Vice-Admiral Tydeman, who had had the command of the „Siboga”, furnished me with very valuable information, but of course he could not recollect all the details of 30 years ago. While in Berlin on the occasion of the centenary of the Berlin Geographical Society, I heard some important lectures on the latest and contemplated explorations. The leader and the members of the expedition likewise furnished me with valuable information for selecting the best positions for various apparatuses. As regards the care and maintenance of the apparatuses, the accuracy of the observations and the personnel required for the various duties, in order to be fully posted I had, however, to rely mainly on what had been published about previous explorations. Good practical hints are particularly given by Tydeman in „Siboga-expedition. Description of the ship and appliances used for scientific exploration” (published by E. J. Brill, Leyden).

Great assistance was rendered me by the Head of the Hydrographic Department of the Ministry of Defence, captain J. L. H. Luymes, whose interest never flagged in everything concerning the expedition and who repeatedly served me with good advice and was always ready to use his influence in surmounting difficulties.

I am also indebted to the designer of the ship, the engineer Mr. L. Troost, for his pleasant co-operation and readiness to meet my wishes.

B. THE SHIP AS SURVEYING VESSEL

H.M.S. „Willebrord Snellius” was destined for the Hydrographic Service in the Dutch East

Indies and was specially built for that purpose. The plans were made by the Navy Department and the building of the ship was entrusted to the firm of „Feyenoord” at Rotterdam. The keel was laid on February 23rd, 1928 and the ship was launched on August 14th in the same year.

The designed dimensions were:

length over all 62 metres
 extreme breadth 9.7 „
 designed draught 3.4 „
 Displacement at that draught: 1055 tons

propulsion: one triple expansion engine

fuel: oil

capacity fuel oil bunkers 193 m³

capacity fresh water tanks 116 m³

accommodation for:

commander, 8 officers, 7 European and
 3 native warrant officers,

12 European and 4 native petty officers and
 men.

boats:

1 motorboat 28',

2 motorboats 26.3',

1 jolly-boat,

2 flats.

hydrographic equipment:

1 large Lucas sounding machine

1 Kelvite sounding apparatus

2 echo sounding apparatuses

1 good-sized draughting room

1 dark room for developing

1 airplane-carrying space.

The cabins, crew's quarters and store-rooms were well-proportioned, but there was little free deck space.

C. REQUIREMENTS OF THE EXPEDITION

Extra accommodation had to be provided for 7 members of the expedition, 1 instrument-maker, 2 native assistants and 1 draughtsman. Furthermore, in order that the work could be continued day and night, the crew had to be supplemented, so that the total number of the crew had to be increased from 85 to 108. Finally, for the purposes of the expedition, room had to be found on board for: a device for anchoring at 5000—6000 m depth; two electric winches for hauling in series of water samples, etc. (winding machines for serial observations); a device for dragging on the sea-bottom and fishing; three laboratories (chemical, biological and geological), and numerous instruments, spares, cables, sounding wire lines and glassware. More than 100 cases of glassware and spare parts had to be stowed on deck and in the store-rooms, outside the laboratories. The total extra load was about 40 tons.

D. PREPARING THE SHIP FOR THE EXPEDITION

In order to meet all these requirements without making any radical alterations in the ship considerable difficulties had, of course, to be overcome, and in this we succeeded, although at some inconvenience.

For the deep-sea anchoring equipment there was just enough room available on the fore-castle deck. The winding machines were placed on the main deck behind the fore-castle and the laboratories were set up on the boat deck where originally space had been left for carrying an airplane. The fishing and dragging equipment was only for shallow depths, with small nets and drags, so that the existing derrick (calculated for a load of 2 tons) and the boat winch (tractive power 5 tons) could be used for this purpose.

The draughting room was converted to accommodate the leader of the expedition and his wife Mrs. van Riel. The biologist and the geologist were each accommodated in their respective laboratories. Two of the members of the expedition were quartered in officers' cabins and one in a warrant officer's cabin.

In order to stow all the instruments and cases a detailed plan had to be made in advance for stowing all the ship's and expedition's inventory, and the cases had to be made to certain dimensions according to the space allotted to each.

The lack of a draughting room was felt as a great inconvenience.

Two officers' cabins were made available by managing with three naval officers instead of five.

It was found, however, that this number was too small to be able to cope with the work, so that eventually a fourth officer was taken aboard, who had to share a cabin with one of the members of the expedition.

In the quarters for the European petty officers and men room had to be found for 15 to 18 persons instead of 12, which was all the more troublesome on account of a large part of the deck space on the boat deck having been taken up by the laboratory deck-house.

The great weight of the deep-sea anchoring equipment ($11\frac{1}{2}$ tons) and the two winding machines (5.9 tons) brought the ship $1\frac{1}{2}$ dm down by the head. This weight on the foreship, together with the load of the laboratories (6.1 tons) aft, aggravated the pitch and, what was worse, the extra load of $23\frac{1}{2}$ tons high in the ship diminished her stability too much. In order to counteract this it was necessary to carry additional solid ballast in the bottom of the ship, to change round a washing-water tank and a ballast tank (thereby gaining 24 tons in water ballast), and during the voyage not to use up all the fuel and water. As a result of these extra loads the mean draught was increased to 3.7—3.8 m and the corresponding water displacement to over 1200 tons.

As a further result of the ship lying deeper in the water, during the expedition, than what it was built for, the between-deck side scuttles could hardly ever be opened while at sea, and when the ship listed heavily, her stability was greatly reduced. In view of this last mentioned evil, subsequently at Soerabaya the space aft between main deck and boat-deck in the open part of the ship was blinded-off.

In the beginning of November 1928 the principal officers, warrant officers and men were put on the finishing work, and on December 20th, 1928 the trial trip was made.

E. DESCRIPTION OF THE EXPEDITIONARY SHIP

The following description is given with reference to figure I, beginning from the uppermost deck, the measuring bridge, situated round the foremast and 9 m above water; here the standard compass is installed and a venetian-blind cupboard contains the self-recording meteorological instruments, behind which is the self-recording rain gauge. Of the whole ship this small bridge offers most free deck space, and from it one has an uninterrupted view on all sides; it is too remote, however, and mostly too windy to be used very often as promenade deck.

Steps lead down at the rear to the small deck below at the back of the chart-room, where most of the space is occupied by the skylight over the cabin of Mr. and Mrs. van Riel. By the side of the skylight are two water tanks, from which the whole ship is supplied with fresh water through pipes. Against the rear wall of the chart-room are various recording instruments, lead-lines and reels with spare sounding wire, all adequately sheltered against rain and sea-water breaking over the ship.

In the chart-room, space had to be found for the nautical books and charts (of the latter no less than 460!), 2 current meters, spare parts and some more reels of sounding wire, whilst in the same room also the recording apparatuses of the Atlas and Hughes sounders were installed and the echoleadsman made his observations there; a little more space would certainly have been desirable.

The navigating bridge, in front of the chart-room, offers sufficient space. On the starboard side is the big Lucas sounding machine, and on the port side the Kelvite machine. On this bridge there are also installed the chart table, steering wheel, steering compass, engine-room telegraph, speaking tubes, sea and air thermometers and a small chest with bottles for surface-water samples. Small searchlights on the wings and a powerful searchlight in top are useful for picking out beacons and buoys when navigating at night in narrow channels and also for fishing and dragging by night. Small shade lamps are provided for reading the sextant when making astronomical observations without hindering the observers. A large five-bulb lamp over the Lucas machine is necessary for operating that apparatus, but it blinds the officer of the watch. On the awning in front of the bridge is an ordinary rain gauge.

Two stairways, one on the starboard and one on the port side, lead to the forecastle and boat deck. On the short forecastle deck is a hatch giving access to the boatswain's locker, a large anchor capstan, 4 air shafts, a grid with mooring hawsers, bollards, a reel for a steel hawser, a coaming and a small skylight. Furthermore there is the whole of the deep-sea anchoring equipment and a small winch for lowering and trimming the small spars of the winding machines.

Behind the forecastle is the captain's cabin. Sliding windows and doors allow light and air to enter from all sides and give a free outlook. Behind the saloon is the sleeping cabin and pantry, and a bathroom with lavatory. Then follows the cabin of the leader of the expedition and his wife; the big skylight and a draughting table remind one of the purpose for which it was originally intended. This cabin has a floor space of a little more than 6×4 m, sliding windows in the rear and side walls and doors at the sides. On both sides of this foremost deck-house some deck space has been left free to pass along, but much of it is occupied by the stairs leading to the bridge and by the rigging and backstays of the fore-top mast. On the starboard side against the saloon is a small tackle for lowering and trimming the small spar of the Lucas machine, and against the railing two sounding tubes are tied up. Outboard on both sides is a 1000 candle power lamp for lighting the serial cables, and to port a canoe is suspended.

Proceeding from the cabin of the leader of the expedition to the laboratory deck-house aft along the boat deck, there are hanging in davits outboard on the starboard side a large motor-boat, a jolly-boat and a flat, and on the port side two smaller motor-boats and a flat. The motor-boats are fitted with Kitchen rudders, thus making it unnecessary to manoeuvre with the motor itself.

Behind Mr. and Mrs van Riel's cabin the space on the boat deck is occupied in the middle by the funnel and by the hood of the boiler-room, engine-room and galley, by chests for potatoes, vegetables and life-saving equipment, and by 4 drums of benzine and 2 drums of alcohol. On the port side is the carpenter's bench and most of the time laundry is hung out there. Bunches of bananas, meat safes, water kegs for the boats, oil drums, spars, planks and belts, all give this part of the deck the characteristic appearance of a surveying or expeditionary ship.

Around the boat winch and the wireless room there is a little more space, at least when the laboratory people are not packing or unpacking cases of glassware. Here there is a so-called recreation table and in the evening a wireless concert is given. Many of the European crew hang up their hammocks around the boat winch, where they find an airy and well-sheltered spot to sleep. Near the galley hood is the fishing cable, and the space aft of the mizzen mast is taken up by the laboratory deck-house.

Passing down one of the four stairways — near the galley or behind the saloon — we come on the main deck below. Only at the forecastle is the hull extended to the boat deck. The deck-houses are from 1 to 2 metres away from the outer edge, leaving an open deck along both sides. Doors and sliding windows provide for fresh air from all sides and enhance the comfort of the well-furnished rooms.

Under the forecastle, behind the boatswain's locker is the sick-bay with 4 beds and dispensary.

Behind the sick-bay is a passage from starboard to larboard of the main deck, in which the two winding machines for serial observations are installed, one at each end of the passage, and further the desk where the reversing thermometers are read off, and racks for water bottles, plankton-catcher, etc. A staircase leads to the clerk's cabin, the refrigerating and cooling chambers and various store-rooms. The Atlas transmitters are placed here in a water hold on the port side. The refrigerating and cooling chambers have a total capacity of 7.5 m^3 . Between the winding machines and the deck-house a not too stout man can just pass along.

About 12 m farther aft is a second cross-passage between the messroom deckhouse- and the boiler- and engine-room hood, just where the two main accommodation ladders are situated. In the passage, against the boiler-room hood, is a large rack for 30 water bottles, with easily removable doors and so arranged that water can be drawn from the bottles while they are standing in the rack. Further there are racks for the four-litre and bottom-water bottles and inverting frames, and a cupboard for dry plankton nets. From this corridor a door opens on to a hall giving access to the messroom, pantry, photographic dark room, bathroom and lavatory, from which passage a companionway leads down to the steerage. The mess-room has a area of about 6×4 m and is fitted up to accommodate 12 members of the expedition and officers. By the companion way the mercury barometer and the recorder of the surface temperature are hung up.

Adjoining the steerage are the cabins of the officers and 2 members of the expedition, the space of each cabin being a good 6 m^2 and 2.30 m high. A ventilator supplies fresh air from the outside through pipes into the cabins, in each of which there is also an electric fan; nevertheless it is often stuffy and the temperature is always around 31°C .; apparently the fresh air supply is inadequate

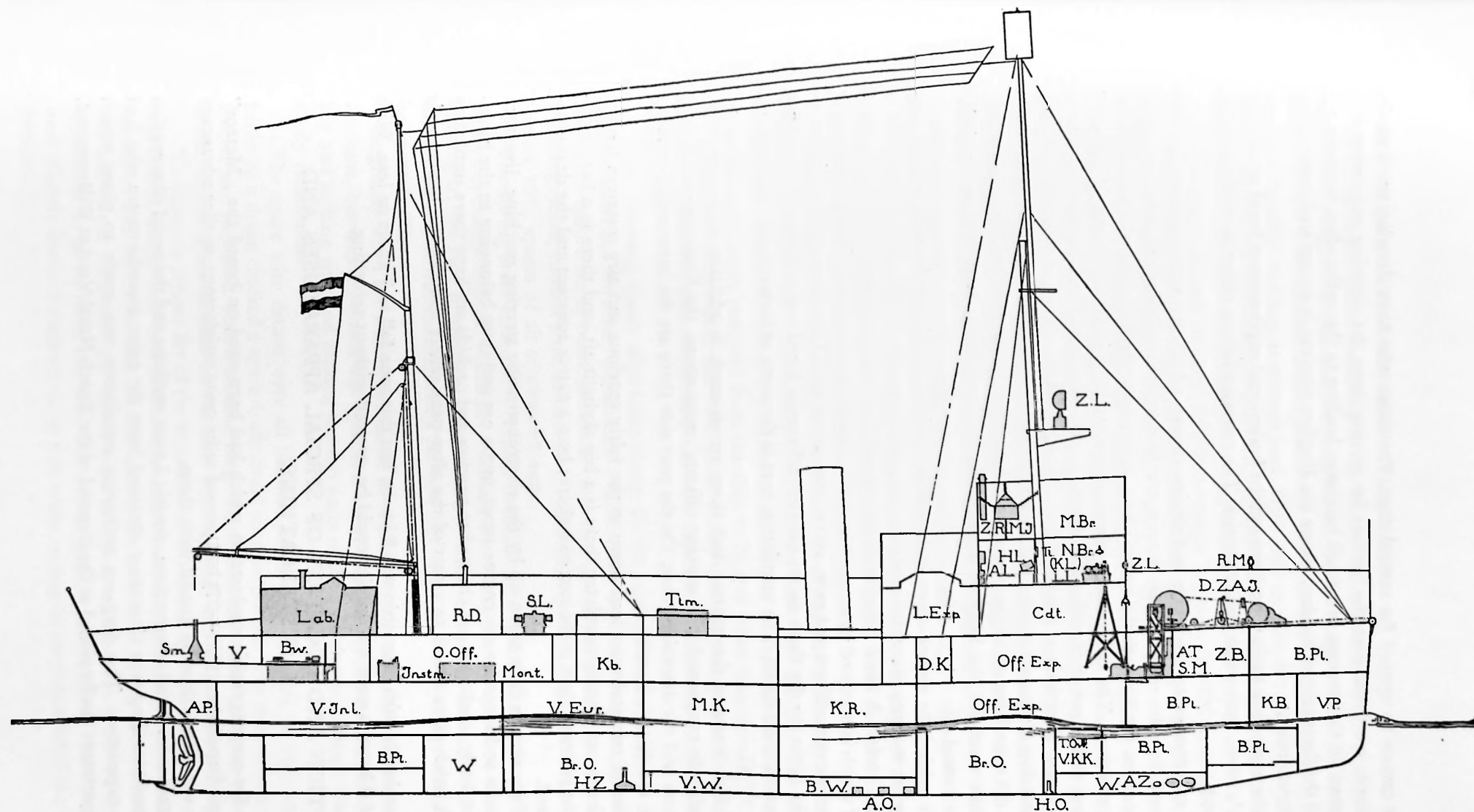


Fig. 1. Vertical longitudinal section of the expedition-ship.

Z.L. = Searchlight
 M.Br. = Upper bridge
 Z.R.M.I. = Registering meteorological instruments
 R.M. = Rain gauge
 N.Br. = Navigation bridge
 Tl. = Air-thermometer
 (K.L.) = Kelvite sounding machine
 L.L. = Lucas sounding machine
 H.L. = Hughes recorder
 A.L. = Atlas recorder
 D.Z.A.I. = Deep-sea anchor gear
 Cdt. = Cabin
 L. Exp. = Cabin of Leader Expedition
 Tim. = Carpenter's bench
 S.L. = boat winch

R.D. = Wireless room
 Lab. = Laboratories
 B.Pl. = Locker
 Z.B. = Sick-bay
 A.T. = Desk for reversing thermometers
 S.M. = Machines for serial observations
 Off. Exp. = Mess-room, cabins
 D.K. = Dark room
 Kb. = Gally
 Instrm. Mont. = Fitters bench, Instrumentsmaker's bench
 O. off. = Warrant-officers mess-room and cabins
 Bw. = Lathe and bench
 V. = Cattle
 Sm. = Forge

V.P. = Fore-peak
 K.B. = Cable-hold
 K.R. = Boiler room
 M.K. = Engine room
 V. Eur. = Quarters european crew.
 V. Inl. = Quarters native crew
 A.P. = After-peak
 A.Z. = Atlas-transmitters
 T.Ow. = Registering sea-thermometer
 V.K.K. = Refrigerating chambers
 W. = Fresh water
 H.O. = Hughes-receiver
 Br.O. = Oil bunker
 A.O. = Atlas-receiver
 B.W. = Ballast-tank
 H.Z. = Hughes-transmitters

when the side scuttles cannot be opened for several days. For those who have drawing work to do, removable drawing-boards are fitted over the berths; for storing away the drawing requisites it is difficult to find any room. In the steerage is a small hatchway leading to the coffer-dam between the refrigerating room and the foremost oil bunker, where the Hughes receiver is set up and some of the biologist's cases are stored away.

On ascending to the main deck again we see around the boiler- and engine-room hood an electric bakehouse, the butler's room, bathrooms and lavatories. The passages left on either side of the deck-house are only 1 m wide.

On both sides is an entrance to the boiler and engine rooms, which are very spacious, so that room could also be found there for reels of spare wire, spare drums of the winding machines for serial observations and some cases. Underneath the boiler-room, in the water ballast tank, on the starboard side are the six Atlas receivers. The temperature there, when the ship is under steam, is certainly high (about 42° C.), but this is not so troublesome thanks to the space and good ventilation. When the ship is not under steam electricity is supplied by a Diesel dynamo; there are sundry electric pumps, so that when the ship is moored or riding at anchor no fuel for the boilers need be consumed.

On either side of the tunnel are oil and water tanks. To starboard a part of the Diesel oil bunker has been taken to make room for the Hughes transmitter. Some packing cases and instruments could be stored in the tunnel.

On the main deck behind the engine-room is the galley, which is equipped for oil-burning. On either side of the galley are washing places for crockery, pots and pans, etc.; cold water is drawn from a tap connected up to a cooler. A third transversal passage behind the galley leads to two warrant officers' cabins, one of which is occupied by a member of the expedition. A stairway leads down to the quarters for the European petty officers and men, and to the cabins for 4 European and 3 native warrant officers. Part of the cabin for the three native warrant officers is fitted out as mess-room, where also one native assistant takes his meals. The ventilation here is the same as forward, the temperature always being around 31° C.

In the aftermost deck-house on the quarter deck there are situated, in addition to the two warrant officers' cabins already mentioned, the warrant officers' mess-room, the boatswain's cabin, a pantry, a hammock store and the detention room. On the port side there are the instrument-maker's bench and lathe and the fitter's bench.

From this deck-house two stairways lead down to the fairly spacious and airy quarters for the native crew. In addition to an electric ventilator there is a big skylight aft, and there is a better circulation of air down the stairway than is the case elsewhere; here a native assistant and the draughtsman are accommodated.

The after part of the ship is fully taken up by the electrohydraulic steering machine, livestock and hay, the bench, lathe and forge for the engine-room, and a net and drag belonging to the biologist. Fowls run around freely, cockatoos are chained to perches and orchids are kept there until they can be taken home. A hatch gives access to a part of the after-peak where some of the boatswain's goods are stored.

The best speed attainable with clear ship was 8 knots, but this soon fell to 7 knots or less. With the economic speed of 8 knots a good 4800 miles could be covered without refuelling.

F. DESCRIPTION AND LOCATION OF SPECIAL APPARATUSES AND INSTALLATIONS

The apparatuses for oceanographic exploration which had been used on board the „Meteor” for the German Atlantic Expedition (1925—27) had proved to be quite satisfactory, so that advantage could be taken of the experience thereby gained with them.

The winding machines for serial observations, the big Lucas machine and the serial observation cables, anchor cable and sounding wire lines were obtained from the same manufacturers who had supplied the Meteor-expedition. The deep-sea anchoring installation was made to plans which the German Navy Department kindly placed at the disposal of the Dutch Naval Yard at Willemsoord.

a. THE LARGE LUCAS SOUNDING MACHINE.

This machine, made according to the known Lucas patent by the firm of Mohr & Federhoff at Mannheim, weighs 1.2 tons and was installed on the starboard wing of the bridge. For reeling-in it is provided with a compound motor, connected up to the ship's electric mains (tension 110 volts) and having a capacity of 4 h.p. at normal load. With 2000 m wire of 1.0 mm still on the drum, the motor could exercise a tensile force on that wire of 140 kilos. This tensile force was barely sufficient. The rate at which the wire was wound up averaged $2\frac{1}{2}$ m/sec.

The drum can take at most 13000 m wire of 1.0 mm, or 5000 m of 1.55 mm wire.

The machine was set up parallel to the board, where the spring lever stood perpendicular and protruded 4 dm outboard.

In order to minimize the risk of the wire line coming up against or underneath the ship, the wire was passed over a fixed pulley attached to the plate edge of the boat deck perpendicularly underneath the spring lever, to a block suspended from a small spar, this block being swivelled and movable in all directions. This spar was rotatable and attached on a level with the main deck railing, being lowered or trimmed by means of a small tackle on the boat deck. The points of rotation of the small spar were placed in such a manner that the block at the extremity, when lowering and trimming, moved in the vertical plane of the spring lever and the fixed guide pulley. With the spar in the horizontal position and the sounding wire hanging vertically in the water, the latter was 3.30 m away from the ship (see figures 1 and 2).

It is advisable to use a swivel attachment for the block at the end of the spar because if the movement is only a hinged one fore-and-aft and athwart-ships, when the wire inclines forward or aft the weight of the block bears too heavily on the slanting wire.

This arrangement has answered very well. Lowering and trimming, which was only done at the beginning and the end of a sounding, could be done easily and quickly. The instruments could easily be attached or detached from a position on the ship or on the starboard sounding platform, and the wire was sufficiently removed from the ship to be free when manoeuvring.

The measuring wheel, the fixed guide pulley and the pulley in the swivel block all have a diameter of 175 or 173 mm. No trouble has been experienced from any wear of the wire by passing over the pulleys.

The following spares were taken along: for the machine 2 wire drums, 1 counter, 2 springs with spring-holder for the lever, 4 bushings, 1 brake band, 1 geared wheel and 1 swingle; for the motor 1 main pole coil, 1 set of bearing metals, carbons and carbon-holders; for the regulating resistance 1 set of segments, contact pins, contact pieces and spark guards, 1 spark extinguisher and 2 resistances; further 10% spares of all screws and nuts.

The spring lever ended in a housing containing the measuring wheel and entirely closed except for two openings through which the sounding wire could pass to and from the measuring wheel. The opening at the side of the wire drum was not wide enough to leave the wire free when the lever moved up and down. Consequently the wire had to be guided between wire drum and house over a horizontal roller.

Originally when the wire drum had to be replaced it was necessary to dismantle a large part of the machine, but this drawback was overcome by making the spindle in two pieces fixed together with a key and locking ring and making the top parts of the side cheeks through which the spindle passed easily removable.

The spare wire drums were all likewise fitted with spindles, so that when the sounding wire broke or a drum cracked a spare drum could soon be put on. The awning over the machine was reinforced and provided with a hauling ring. There was never any need, however, to replace the wire drum, except when another sort of wire was required, and none of the spare parts were used.

To ensure a proper lay of the windings on the drum we installed two hardened and almost vertical rollers which were moved to and fro and between which the wire was guided; these rollers were moved to and fro by turning a hand-wheel, the motion of which was transmitted via a worm-gear and nut to the jib where the rollers were attached, which made it necessary to make these rollers removable so as to leave the wire free of the guides when paying out. These small guide rollers were slightly inclined backwards, so that when reeling-in they were lifted slightly, thus reducing the friction.

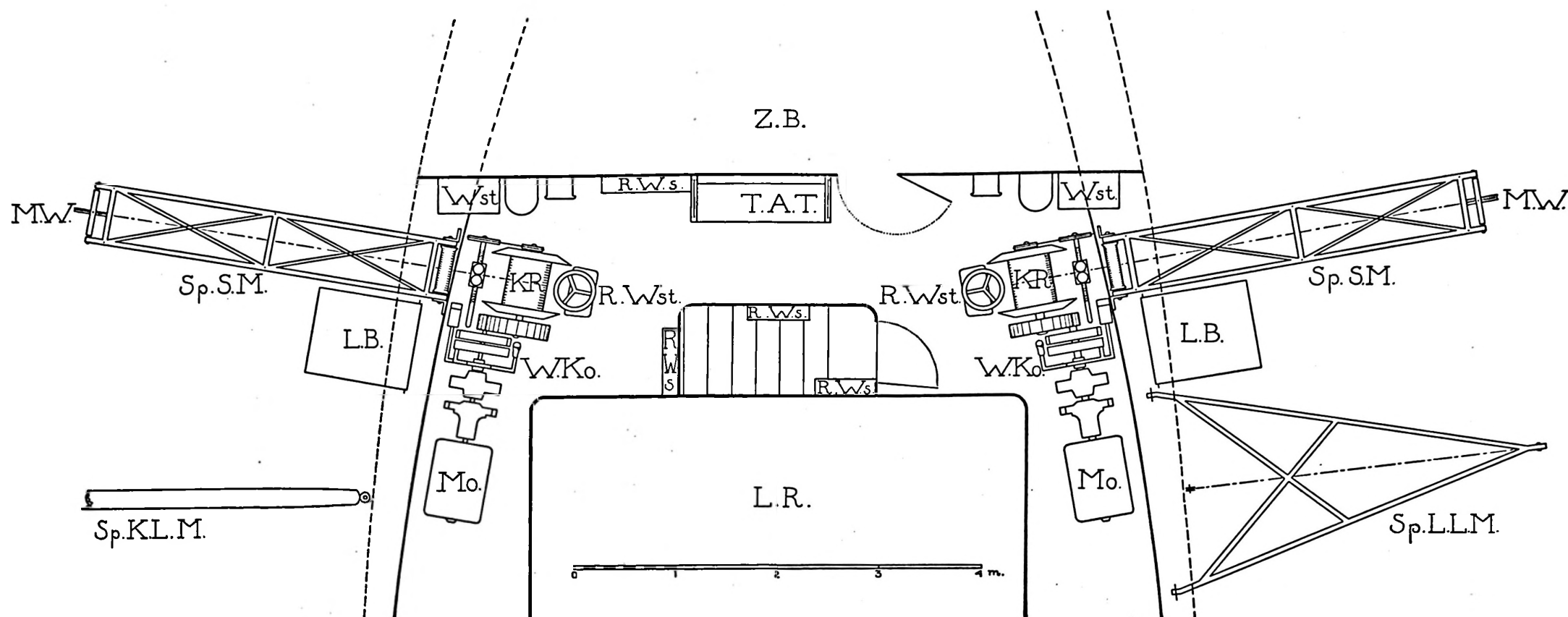


Fig. 2. Appliances for bottom and serial observations.

Z.B. = sick-bay
 L.R. = mess-room
 Sp.S.M. = spar serial machine
 Sp.L.L.M. = spar Lucas soundingmachine
 Sp.K.L.M. = spar Kelvite soundingmachine

L.B. = sounding platform
 T.A.T. = table for reading the thermometers
 K.R. = wire drum
 R.Wst. = regulating resistance
 W.Ko. = brake coupling

Mo. = motor
 M.W. = measuring wheel
 Wst. = resistance
 R.W.s. = racks for waterbottles

For sounding wire we used piano wire of 1.0 mm and stranded wire of 1.55 mm section. Various properties of these wires are given in appendix No. 1.

When the sounding wire is first wound on the drum it is necessary to keep it well under tension, just as is done when sounding. If this is not done, then, even if otherwise particular care is paid to the winding, the windings will be loose and run foul of each other. If it is tried to remedy this by carefully running the wire out into deep water the slack keeps springing back on to the drum instead of going outboard with the line, with the result that several thousands of metres have to be paid out before the slack, which may be only 1 cm, is removed. We found the best course to be, when winding up for the first time, to wind the wire from the reel first on to the big cable drum of the starboard winding machine — after covering the cable with laths — and then from the cable drum on to the drum of the Lucas machine. The desired tension (20—70 kilos), which was read off a tension meter (see figure 3), was obtained by braking the cable drum with the friction coupling of the winding machine. This is a quick method but involves the risk of the wire line breaking.

The piano wire was supplied on reels of 11000 metres, but in this length there are three joints, and these were the weak points in the line. Our experience showed the best manner of joining to be the following:

The ends to be joined, after being thoroughly cleaned, are laid crosswise over each other with a metre of each end extending beyond the cross, which is held in a hand vice. Each loose end is then wound round the other fixed part, beginning at the cross, care being taken to lay the strands uniformly so that they cannot slip, and to make them as short as possible and yet long enough for the wound-on part to lie up true against the fixed part; there must not be any kinks in the wire. The speed of our wire was about 2 cm. The strands were held in place with six seizings of very thin wire, two of which against the cross and two at each end, these seizings then being made fast by fluxing with tin solder; the soldered parts were washed with fresh water.

If the strands are not properly laid or the speed is not uniform then there is not sufficient friction between the two wires, force is exercised on the seizings, these break and the joint comes apart.

The joints have to be inspected before every sounding, on account of the solder being worn away in course of time by the great pressure on the drum and the pressure of the water, and when the solder has gone there is a great risk of a seizing breaking or working loose.

Whenever two sounding lines of stranded wire had to be joined together this was done with an ordinary long splice.

Although the joints in piano wire of 1.0 mm need careful attention I nevertheless prefer this wire to stranded wire. Piano wire does not rust, so to speak, is more durable and lighter than stranded wire and has less resistance in the water. Any damage to the piano wire soon strikes the eye. Probably stranded wire causes much wear of the measuring wheel and guide pulleys, whereas piano wire causes hardly any wear at all. Kinks need not occur with deep soundings. Breaks in the line only occurred at badly made joints (before we had acquired sufficient experience in the work) and as a consequence of inattention on the part of the men operating the machine.

The sounding line was provided at the end with a wrought thimble. When stranded wire was used this thimble was spliced in. The manner in which the thimble was attached to the piano wire is shown in figure 4. In order to ensure that the piano wire bears evenly around the thimble, at about

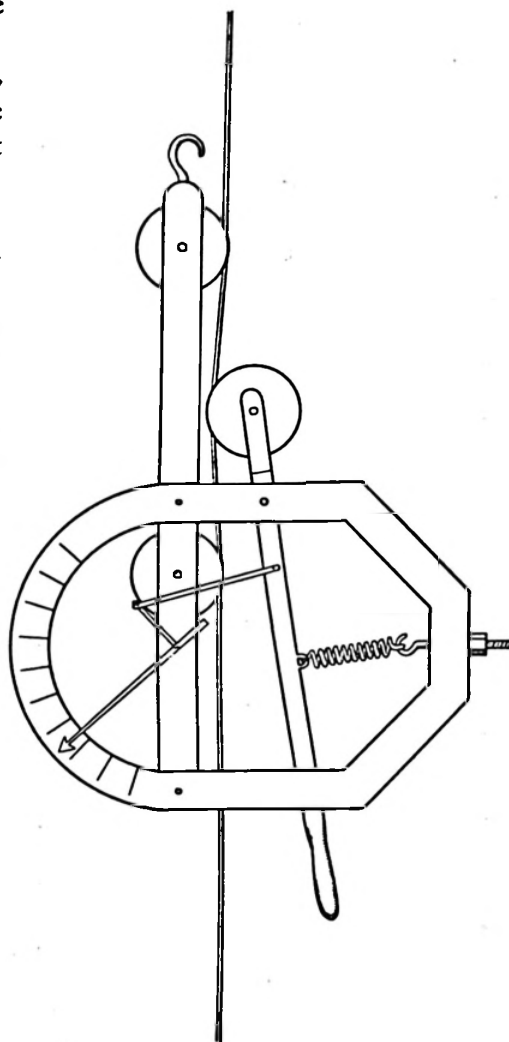


Fig. 3. Tension meter.

70 cm from the end the wire was pressed in a gauge until it assumed a true circular shape with a circumference as large as that of the groove in the thimble. After the wire had been laid in the groove the edge of the thimble was closed up with a templet and fluxed with tin solder.

At the bottom end of the sounding line there were attached, in the order given: a lead of 2 kilos with true-ground swivels at the ends, a length of serial cable for attaching water bottles or inversion frames, a stray-line of lead line weighted with lead, and attached to this the sounding tube or snapper (see figure 4.)

The piece of serial cable was generally required for one or two instruments, but sometimes a series of water samples and temperature recordings from close to the sea-bottom were required, and then a cable of about 90 m in length had to be used.

We never lost any wire through torsion. Several times it was noticed, however, when the 2-kilo lead came to the surface, that the swivels were rotating swiftly. There was always a certain amount of torsion left in the end of the wire, but too little to overcome the friction in the swivels; this was noticed mainly when using stranded wire. On the lead being lifted the wire kinked in several places and the end had to be cut off.

The stray-line of lead line was mostly 30 m long. It was found necessary to weight it with ballast lead, as it sometimes happened that the lead line got entangled with the water bottles above, particularly when the wire was paid out a little more in the hope of getting a long bottom sample.

For stoppers we used the nipper as illustrated on figure 5. In the edges pinching the wire a groove was made slightly less in depth than half the thickness of the wire. Good stoppers are indispensable, and these answered quite well.

Before beginning to reel in a tension meter was attached to the apparatus (see fig. 3). While the sounding tube was being drawn out of the ground the tension was observed so as to keep clear of the limit of breaking strength of the wire. Once, it occurred that the tube could not be lifted with the motor and the ship itself had to lend assistance; the tension then rose to 160 kilos. When pulling the tube out it is always advisable to put on the brake a little, as otherwise the tube may suddenly shoot out of the ground. After pulling, the tension meter was removed so as to avoid unnecessary wear of the wire.

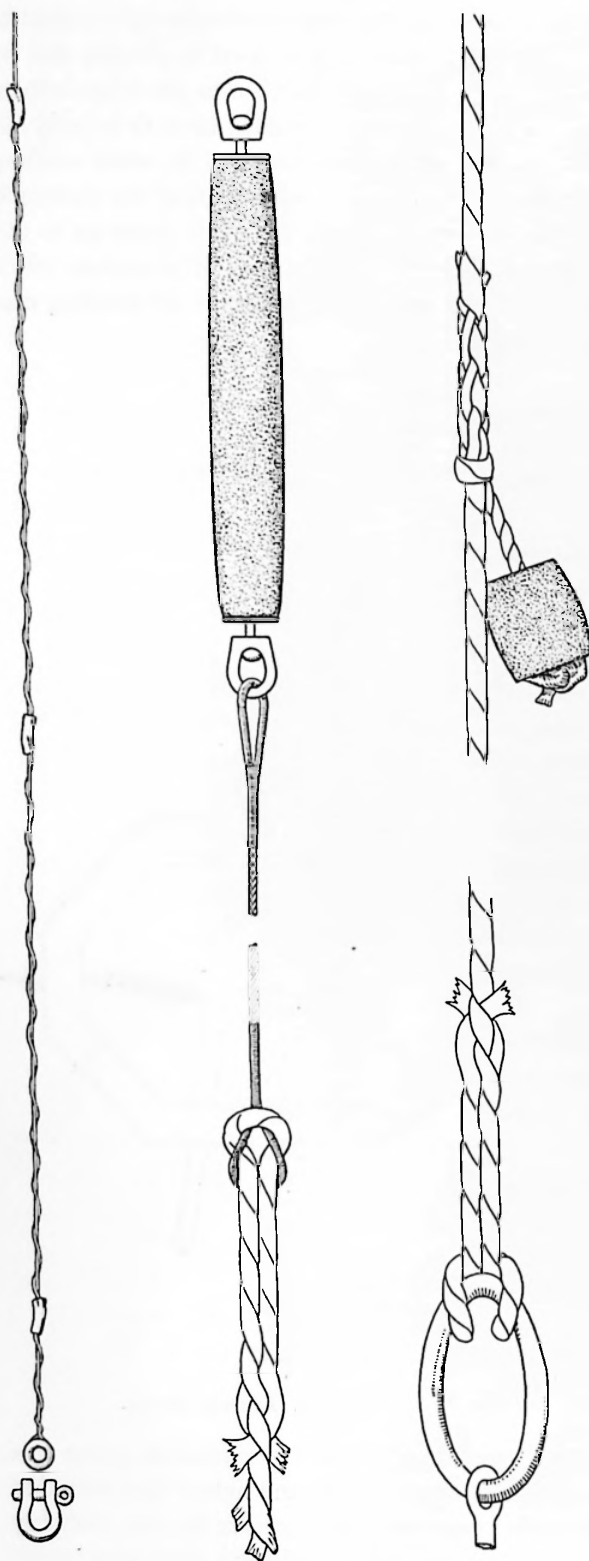


Fig. 4. How the bottom sampler was attached at the piano wire.

On being wound up the wire was dried — care being taken with the joints — and greased. When cared for in this way piano wire does not rust, except for the extreme end, which is always exposed to weather and wind. Apparently rain water has a more corrosive action than seawater; in

the rainy seasons the exposed end of wire had to be cut off every two or four weeks and the thimble affixed anew.

Sounding was under the supervision of the geologist or one of the oceanographic experts, who personally controlled the withdrawal of the sounding tube out of the ground and the winding up of the last 50 metres. The instruments were attached by the echo leadsman of the watch, and two other men had to be in attendance. The rate of running out was 3 to $2\frac{1}{2}$ m/sec and that of reeling-in $2\frac{1}{2}$ m/sec. Including the time taken for attaching and detaching the instruments, a sounding of 2000 metres took half an hour, one of 5000 m $1\frac{1}{4}$ hours and one of 10000 m $3\frac{1}{4}$ hours.

The weights of the instruments attached to the end of the line, when suspended in the water, were about as follows:

1 sounding tube of 30 mm	32 kilos
1 " " " 20 "	29 "
1 bottom snapper	26 "
1 water bottle	$4\frac{1}{2}$ "
1 inversion frame	3 "
lead, stray-line, etc.	3 "

The total weight of the attached instruments was generally between 28 and 44 kilos. For soundings of more than 5000 m usually the Sigsbee lead with dropping ballast weights was used.

b. THE ATLAS SOUNDER (Atlaswerke, Bremen).

The principal parts of this apparatus are:

a) The transmitters, two large ones of the A type and a small one of the D type, with diameters of 0.67 and 0.32 m respectively, installed on the port side in the foreship in the double bottom at a distance of 1.05 m apart. Owing to their position fore, the transmitters are slightly inclined, about 4° along-ship and 25° athwart-ship. The duration of vibration of the A transmitters is $\frac{20}{1050}$ sec and that of the D transmitter $\frac{3}{1050}$ sec.

b) The receivers, six in number of two types and with diameters of 0.20 and 0.40 m, installed on the starboard side in the boiler-room at intervals of two ribs and at an average distance of 12 m from the transmitters. The inclination fore and aft is very small, and that athwart-ship 4° .

c) The transformer, placed on deck in the warrant officers' deckhouse.

d) The recording apparatus, the parts for switching in the transformer, switches for transmitting and receiving, measuring instruments and reception amplifier, all installed in the chartroom, fairly compact and easily accessible in two columns about $2 \times 0.5 \times 0.4$ m.

The transmitters were installed while the ship was in dock; they were fitted in from underneath and fastened to the hull with bolts and red lead; the inner parts of the transmitter need no attention for upkeep.

The transformer converts the ship's direct current of 110 volts into alternating current of about the same voltage and with a frequency of 525.

Two kinds of receivers were used, the microphone- and the rubber-receivers. In the first type the microphone is simply screwed into a membrane fitted in the hull, while in the second type the microphone is encased in rubber and hung up in a case filled with water.

The case of the recording apparatus contains the clockwork proper for registering the echo time, i.e. the time elapsing between the transmission of the sound and the reception of the echo. The sound travels to the sea-bottom and back, so that half the echo time multiplied by the mean velocity of sound in the water between the surface of the sea and the bottom is equal to the distance to the reflecting plane at the bottom.

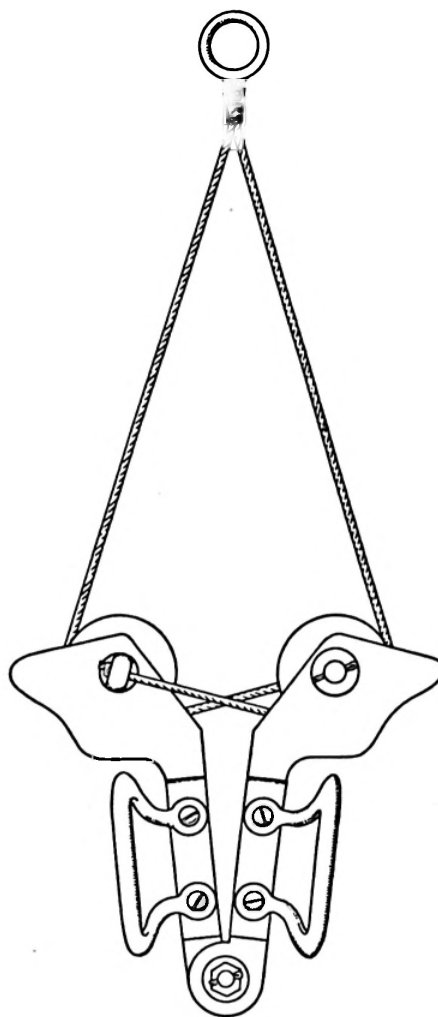


Fig. 5. Stopper.

The Atlas sounder is of robust construction and, at least as regards the installation for deep sounding, absolutely reliable. In all it has been in use for 275×24 hours, during which time it only failed us for a couple of hours. The transmitters, however, soon get corroded; after being in use for a year they were badly pitted all over, in some places 4 mm deep, and six months later the metal at those spots had been eaten away still more and further pits were to be seen, so that it was deemed advisable to replace the big transmitters by new ones. The recording apparatus, moreover, is built in somewhat too compact a form, repairs necessitating a lot of dismantling. For the rest, the working of the apparatus is simple, the echo is easy to follow and the whistling tone is not very fatiguing. Secondary echoes are easily distinguished, and from their nature it can generally be deduced whether a steep slope is being approached, which is of great advantage for safe navigation. For navigation it is a very good apparatus, but for hydrographic work it is not so accurate as might be desired. Its accuracy is mainly governed by the degree of accuracy with which the revolutions of the indicating motor can be regulated, further by the accuracy with which the moment can be estimated at which the echo is heard, and finally by the reaction time of the leadsman. The speed of revolution of the indicating motor is regulated by means of a frequency meter, a method which is not very accurate. The moment at which the echo is thought to be heard can be estimated to within a degree of accuracy of 15 metres. The reaction time of the leadsman varies, so that if a fixed correction is applied for this error a variable error still remains. Finally the graduation up to 1200 m involves the risk of mistakes being made; a scale up to 1000 m would be better.

The small D transmitter can be used for depths up to a little over 1000 m, and a single A transmitter for depths up to an average of 5000 m, but often also for greater depths. Bad echoes are caused principally by uneven sea-floor. Two A transmitters used together does not reinforce the echo very much. Over a flat part of the Emden deep (10000 m) a clear echo was still obtained with one A transmitter alone, whilst close-by, over undulating bottom, the double transmitter gave only a very faint echo. The receivers placed close to a floor timber were not so distinct as those standing clear.

Our experience with the apparatus for shallow waters, which records the depth automatically, was not so good. Very soon after it had been taken into use the indication for very shallow water was useless and there were many troublesome secondary flashes. With these secondary flashes there is the danger that one of them may be taken for the depth indication, when the ray of light which should indicate the depth has disappeared or was not so clear, either due to inaccurate adjustment or as a consequence of a defect in the apparatus. If this is not detected in time then the use of this apparatus may well be disastrous. Its less satisfactory working was to be ascribed to the transformers, which in the tropics very soon fused, in consequence of which the receiver current had to be reduced and there was thus a greater risk of recording on secondary echoes (secondary flashes).

c. THE HUGHES SOUNDER (Henry Hughes & Son, Ltd., London).

The Hughes sounder consists of the following parts:

a) The transmitter, set up in a compartment on the port side next to the tunnel, together with some auxiliaries, i.e. the air pump and two small water pumps. The air pump is electrically driven and supplies the necessary air to the transmitter at a pressure of 100 lbs/sq. in.

The water pumps are hand-operated.

b) The receivers, one deep-sea receiver and one for shallow water. Both are installed on the starboard side in the foreship at 21 and 25 m respectively from the transmitter; the angles of inclination are 8.5° and 30° athwart-ship and 1° and 5° fore-and-aft.

c) The recording apparatus, in the chartroom.

With the Hughes transmitter a very much damped vibration is obtained by a blow with a pneumatic hammer on a membrane, the vibrations being transmitted via two water cushions to the hull of the ship. The vibration of the hull plate was confined — judging from the pits and growth on the plate — to the bottom of the lower water cushion and was concentrated mainly in the center.

The deep-sea receiver consists of a microphone screwed on to the bottom of a watertight closed metal box. In order to effect a direct communication between this box and the sea water, and thus to attain the highest possible strength of reception, a tank was built inside against the hull, closed at the top and open to the sea water at the bottom. The microphone box can be moved up and down in-

side this tank. When sounding, the box is in the outermost position, and in order to avoid damage from the outside an arrangement has been made for closing the tank at the bottom with a sliding valve.

The recording instrument is contained in a large metal box placed at an angle on the chart table.

Our Hughes sounder was very accurate and the deep-sea receiver quite clear, but it was not so good as our Atlas sounder. Various parts were not strong enough and the transmitter required a great deal of attention. The sound produced by the hammer not being a clear tone, the echo cannot be screened and amplified, and as a result the echo received is weak and difficult to distinguish from various other sounds. In the telephone the sound of the water can be heard, the strokes of the propeller, the main engine and various machinery, and all sorts of other sounds, creating together a rustling, singing, ringing and hammering noise. And among all this, one has to distinguish the blow of the hammer. As a consequence it is difficult to follow the rapid succession of changes in depth occurring in the Indian archipelago, and sounding with this apparatus is very tiring work. If an engine is running which has a period about equal to that of the transmitter, then there is a great risk of the sound from the engine being mistaken for the periodical echo, so that entirely wrong depths will be recorded.

In the beginning soundings were obtained a few times with this apparatus for depths of 2000 to 3000 metres, but very soon only very shallow depths were sounded. After docking on arrival in the Indies, the hull plate underneath the transmitter was found to have assumed a convex form outwards and was badly corroded in the centre underneath the transmitter, and underneath the place where the latter is welded to the hull. This hull plate, which was 11 mm thick, was replaced by a piece of boiler plate 1.14×1.35 m and 15 mm thick, with which plate echoes were obtained for depths up to 800—1000 m.

However, as such shallow waters were seldom met with in the areas explored by us, little use could be made of the Hughes sounders.

For the working of the echo sounders we had 4 echo leadsmen and 2 or 3 reserve echo leadsmen. As a rule one echo leadsmen was on duty for 4 hours at a stretch.

d. THE FISHING AND DRAGGING INSTALLATION.

This installation (see figure 1) served to draw a small drag over the sea-bottom or a net horizontally through the water. The depth at which the net was towed (was regulated simply by the length of the cable run out according to the speed at which the ship was travelling. This installation fully answered the simple demands made of it.

The topping lift of the derrick ended in a thimble carrying a triangular plate with a hole in each corner. The topping lift was fixed through the top hole, a tun chain through one of the bottom holes and a steel cable through the other. The links of the chain could be caught up on a hook at the top end of a series of three rods containing a long and strong spring. This spring served as a sort of accumulator and was of the same type as that used by the „Siboga”, except that in this case there were not two springs built into each other. Two springs with a different period of vibration and built into each other have the advantage that the vibration is soon exhausted, but for our simple installation, which was not exposed to any great forces, such a double spring was not deemed necessary. The big spring stood vertically against the mast, the bottom end being fixed to an eyebolt bolted to the boat-deck. The steel cable affixed to one of the bottom holes of the triangular plate was passed over leading blocks to a barrel of the boat winch and served for lowering or trimming the boom. When the boom was in the desired position, one of the chain links was caught up with the hook and the cable let go. In this way it was possible to get the boom carried in the spring in any desired position.

The derrick block was attached to the extremity of the boom with a swivel and was able to turn about in all directions.

The fishing cable was wound on a reel and from there passed over leading-blocks to a barrel of the boat winch, and further over leading-blocks to the quarter block and derrick block outboard.

When dragging, the fishing cable was held in a nipper of the same design as used for the sounding wires and serial cables (see plate V), except that the groove engaging the cable was fluted, thus reducing the risk of the cable slipping.

In order to avoid damage to the derrick rigging if the drag should catch behind a rock or a block of coral, the drag was attached to the fishing line with a hemp rope in between, and also the stopper was attached to a deck bolt with a hemp rope. In the event of the drag catching, then one of these ropes would break before any great weight was brought to bear on the rigging. Care must be taken, however, that the fishing line cannot get fouled between the reel and winch, and the barrel of the winch has to be held loosely, so that it can slip.

To prevent the small and relatively quiet fish from escaping out of the net, fishing has to be done with a fair speed (about 3 knots) and the line has to be hauled in quickly.

e. THE LABORATORY DECK-HOUSE.

The drawing given in figure 6 shows the peculiar construction of the deck-house, due to the desire for the largest possible space. At the front the space was limited by the davits for the flats and by the mizen mast.

In order to protect the deck where it passed through the compartments in which caustic liquids had to be used, it was covered with sheet lead and on top of that a layer of cement 2 cm thick. The outer walls were made of 28 mm fluted and beaded red deal, the inner walls of 18—25 mm fluted white deal. The deck was made of 80 × 40 mm boards of selected deal, fluted and caulked with cotton threads and asphalt. The walls between the chemical laboratory and those of the biologist and geologist were double walls with a layer of paper in between. The acid cupboard was tiled inside. The table tops in the chemical laboratory were of teak and the sinks of fireclay; the sinks in the other laboratories were of zinc. Salt water and fresh water taps were provided over all the sinks. The drain pipes were led over the deck, so that any leaks would be immediately noticed. Bottles with hydrochloric acid were made fast on deck. A supply of soda was kept continually at hand.

Naturally the internal arrangements were made according to the desires of Messrs Boschma, Boelman and Kuenen. The main aim was to make the best use of the available space and to store as many bottles and other paraphernalia as possible in the laboratories. The purpose and layout of every cupboard and rack had to be previously studied and indicated on the drawings; of course some alterations were subsequently made, but still it is well worth while to work out all these details in advance.

The members of the expedition who worked and lived in these laboratories will give a more detailed account of their furnishing, so that the foregoing particulars will suffice here.

f. THE WINDING MACHINES FOR SERIAL OBSERVATIONS.

The installation of these machines is shown in plates I and II, and their use and maintenance will be dealt with elsewhere, in the oceanographic part.

g. THE BOATS.

The motorboats, which were specially equipped for hydrographic work, were very little used as such. The big motorboat, however, was particularly suitable for long trips. For geological and biological explorations ashore, this boat with two flats was left behind for about 4 days under command of a naval officer. A camp was put up on shore from which excursions were made by Dr. Kuenen with the motorboat and a flat, whilst Dr. Boschma remained behind with the other flat. These camping trips were a welcome change in an otherwise monotonous life, though Dr. Boelman and Dr. Kuenen once got an attack of malaria.

The jolly-boat was particularly useful for diving.

h. THE METEOROLOGICAL INSTRUMENTS.

These instruments should really be installed near the rolling point of the ship, without being exposed to direct radiation but yet so situated that the air can reach them freely from all quarters without first being heated by the funnel or ship, and without causing draughts. On a spacious ship it is already difficult enough to meet all these demands, but on the „Snellius” it was absolutely impossible.

The mercury barometer was hung up in the passage leading to the messroom, and other instruments were put up in a cupboard with venetian blinds suspended on the upper bridge on a heavy

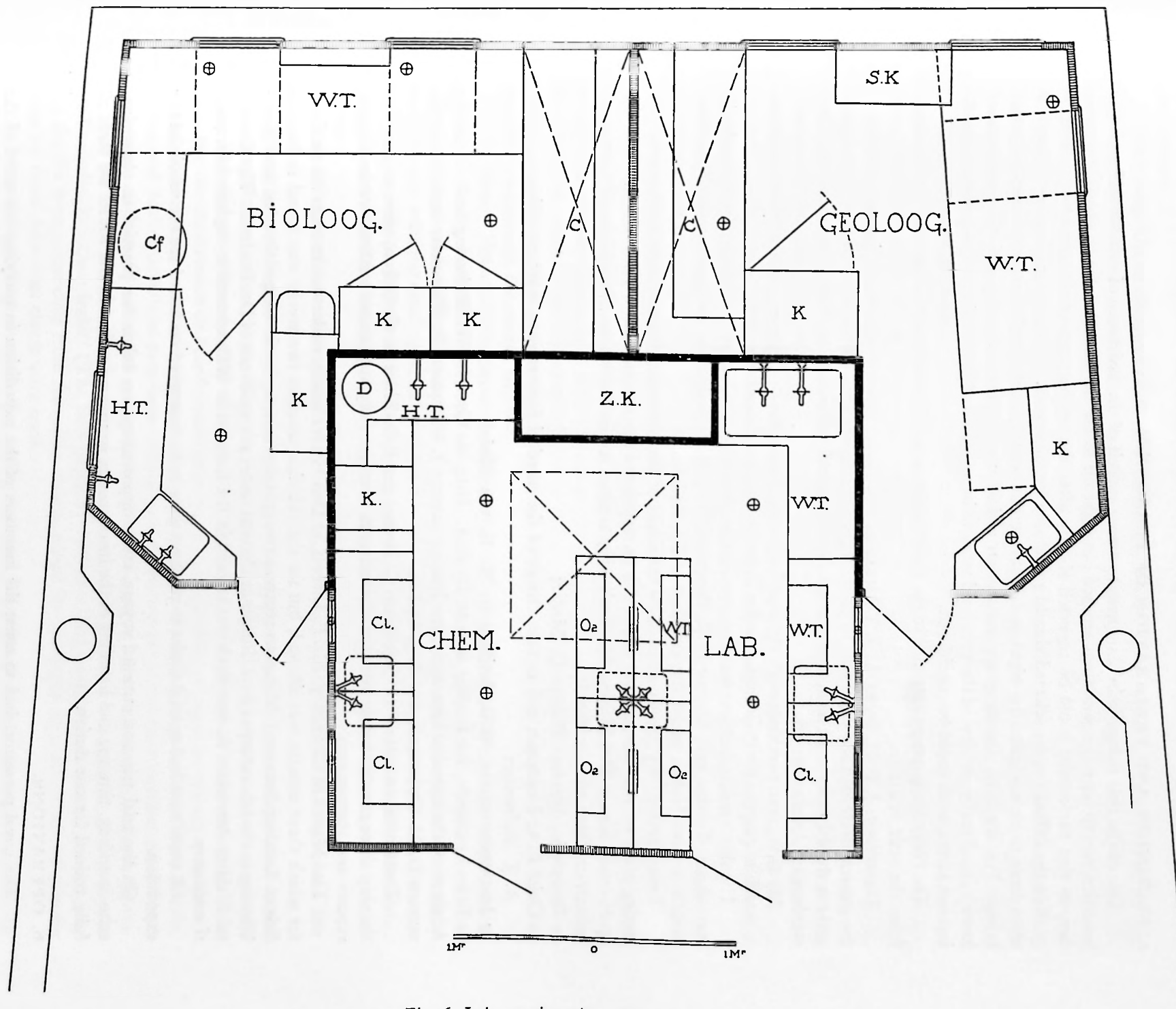


Fig. 6. Laboratories with cabins of geologist and biologist.

W.T. = table
H.T. = inclining table
K = cupboard
Cf = centrifugal

C = berth
S.K. = cupboard for sedimenting
Z.K. = acid cupboard
Cl. = table for determining chlorinity

O₂ = table for determining oxygen contents
D = distilling appliance
⊕ = lamp

double spring, with weaker springs to counteract rocking. This is certainly not an ideal situation. When a strong wind was blowing we had much trouble from vibrations, rocking and rolling.

G. PERSONNEL AND DUTIES

a. SELECTION AND PREPARATION OF PERSONNEL.

One of the first things to be done was to assure myself of the assistance of capable officers. My intention was to have the soundings worked out right up to the fair sheets as far as possible day by day, so that the results could be reported shortly after the termination of the expedition. Consequently the officers to be selected should preferably be surveyors. Furthermore, as the ship would often have to be navigated by night and in dangerous waters, reliable officers were needed on the bridge. For the echo sounding apparatuses an officer was required with special electro-technical knowledge. Finally, in view of the very hard work to be expected of them, only personnel with a keen interest in the work could be considered.

The Navy Department extended to me the great favour of allowing me to make my own selection from the staff available.

Lieutenants J. P. H. Perks, L. J. Veldman and F. H. M. van Straelen, on being approached in the matter, declared their eagerness to go with the expedition. The first two were trained surveyors and the third I knew to be a capable seaman. Veldman had also taken a course of instruction in Amsterdam in electro-technics.

My first correspondence with these officers dated from May 1928, so that they had six months in which to prepare for their duties, as far as their ordinary duties permitted.

The ship's medical officer was to supervise the collecting of plankton on board while the biologist was ashore. To that end, Doctor P. C. Broekhoff studied in qualitative plankton analysis for three months at Den Helder under the guidance of Dr. Redeke.

I was further very greatly assisted by the Chief of the Personnel Bureau at Willemsoord in selecting good warrant officers and seamen to be appointed for special duties. As I myself could not spare much time at Den Helder, Mr. Perks ably assisted me in that matter. From a large number of volunteers there were selected:

as Boatswain, Warrant Officer C. Mallie;

as Chief Echo-Leadsman and to take charge of the nautical instruments, warrant officer-signaller A. J. Woltering;

as Instrument-maker, W.O.-Artificer A. W. H. van Bladel;

as Echo-Leadsman, the leading seamen D. A. L. Hitz, A. Groters, W. Woltering and G. Stolk; Analysts in the chemical laboratory, the leading seamen J. Marquart, P. Wassenaar and the A. B. seamen D. M. Onkenhout and P. J. Louws.

These men, and also P.O.-Signalman C. Becher and P.O.-Fitter A. C. Geljon, were attached to the ship three months before her commissioning so as to get fully acquainted with the various apparatuses and instruments.

The Master of Chemistry, Mr. F. Liebert, at Den Helder kindly undertook to train the analysts for which three months was allowed, but for the chlorine-titration two weeks was found to be sufficient. Leading Seaman J. Marquart received two months' instruction in oxygentitration and glass-blowing in the laboratory of Prof. Ringer at Utrecht under the guidance of Dr. Boelman. The Corporal Sickbay Attendant A. van Beek was trained in the hospital at Willemsoord to replace Marquart if necessary.

All those who had special duties to perform were to be quartered on board for the whole of the expedition.

On the trial trip and outward voyage, every opportunity was taken for practice in observing, echo-sounding, titrating and handling of the instruments, so that on arrival in the Indies we were all fully trained for our duties.

b. OPERATIONS.

The naval personnel had to assist the members of the expedition in carrying out most of the operations, such as wire sounding, taking water samples, fishing and dragging, explorations ashore,

and in the care of the instruments. We had particularly taken for our account the fixing of accurate positions, echo-sounding, plotting and charting the soundings and collecting the normal meteorological observations. Furthermore, Dr. Boelman had continually at his disposal two analysts for assisting him in determining the salinity of the water and one for assisting him in determining the oxygen content.

Reckoning. Up to distances of 30 or 40 miles out from the shore the ship's position was mostly kept by compass bearing, and beyond that distance by astronomical observation. The dawn and twilight position-fixing was done as a rule by two observers and the noon observation taken by two or three. The sun longitudes were taken only by the officer of the watch. As the sun mostly passed through the meridian very high, the noon fix could be made under favourable conditions by combining observations taken at about 11 and 13 o'clock with the noon latitude. Observations were rarely taken at night. Frequently an additional datum for position-fixing could be obtained by crossing at night preferably the 200 metre line.

It was a great advantage that almost the whole of the Archipelago had been surveyed up to the limit of the shallow sea, so that for the terrestrial position-fixing the position of landmarks could be taken to be exact, and the 200 metre line could be taken from the charts.

Of some parts, the survey had been completed but the new chart had not yet been published, and of these parts, tracings of the fair sheets were obtained. Where areas of great extent were concerned, such as the Nenoesa-Talaud group, with the Siao group, the Banggai and Soela archipelago, Boeroe with the Oeliassers and south coast of Ceram, with the aid of these fair sheets first a construction sheet was drawn which served as navigation chart, and on this the ship's course was plotted. The positions of various small islands on the Kawio plateau agreed fairly well with our astronomical observations. The position of the islands near the Siboetoe passage was corrected by a quick survey.

The presumable route that the ship had followed was fixed with the aid of the bearings and observations on the so-called.

Route charts, making use of the direction of current found by manoeuvring on the wire line.

The *echo soundings* were taken, as a rule, at intervals of 5 or 10 minutes, corresponding to distance of about 1200 or 2400 metres. Where the form of the sea-floor was complicated, soundings were taken in rapid succession. From these echo soundings there were constructed *Bottom Sections*, on a scale of 1 : 100,000, both in the horizontal and in the vertical direction. These bottom sections, fitted together on more than 50 large drawing sheets, give a surveyable and detailed picture of the form of the sea-floor underneath the routes followed.

Fair sheets. The area investigated was divided into 17 fair sheets drawn in equi-distant cylindrical projection to the scales and with the boundaries indicated in appendix No. 2. The scales of the „Emden Deep” and „Goenoeng Api” sheets were so chosen in order that the results could easily be compared with the existing charts of those areas and all depth figures shown on them; if the accuracy is considered, however, they are too big. The various sheets to the scale 1 : 1,000,000 overlap each other, this being done in order to be better able to draw the depth lines and to give a handier survey.

The 200 metre line and the coast line were taken from the charts or from the tracings of the fair sheets.

The deep soundings known from surveys made prior to the expedition were re-examined in the Hydrographic Department of the Ministry of Defence, entered on a separate set of charts and placed at the Expedition's disposal by the Chief of that Department. The number of these soundings was 3163. For the charts made on board (construction sheets) the positions of those soundings were checked and corrected; this concerned mainly the soundings of the „Siboga” and the „Edi” off Obi, Boeroe and Amboina. Where data were lacking for a determination of the exact position these soundings were marked off with a tick on the Boeroe Sea sheet to the right underneath the depth figure.

For the vicinity of the Mindanao and Sulu seas, the depths used are those given in „De Zeeën van Nederlandsch Oost Indië” (The Seas of the Netherlands East Indies) for that area, and some 40 odd depths were taken over from American charts, whilst for the depth lines also some 300 depths given on those American charts were used.

A few new soundings near the Kei archipelago and Talaud and Siao were obtained from the captains of the surveying vessels „Tydeman” and „Van Doorn”.

For the compilation of our fair sheets more than 32400 echo soundings of the Snellius expedition and some 3500 soundings of other ships were used. Our echo soundings have been indicated in black and those of other ships in red.

The no-bottom soundings are not given on the fair sheets, but they were taken into account when drawing the depth lines.

The soundings of the „Dana” and the „Emden” (Soerabaya-Endeh-Makassar-Dilly) could not be given to us in time.

Manoeuvring for hours on the stations had a very adverse effect on the relation between the soundings. For determining the course that the ship had followed between two places fixed by reckoning, account was taken of the currents found in that area and on the station; this, however, was more or less guesswork and it is quite possible that what was taken to be drift at a station was not correct. Where such an error was made over a steep slope the result was that in the direction where most probably the depth should increase the depth as shown on the fair sheet diminished. In such cases, when plotting the depth lines, account was taken of the probability of an error in the position of the sounding figures. It also sometimes happened that the old soundings, mostly wire soundings, did not agree with our echo soundings, due for a large part to inaccuracy in reckoning and to the effect of current on the wire soundings.

Where there were insufficient data for drawing the depth lines, these lines have not been drawn in full.

For our *meteorological observations* we followed the plan indicated by the Bilt Observatory for the meteorological ship's logs, but in a somewhat extended form. The surface currents observed were combined on a *current chart*, those found in the two monsoons and at the turns of the monsoons being indicated in different colours.

Registration of the observations. This was done on the same principles as those of the tried system followed on board the surveying vessels, the procedure being the following:

The astronomical observations were recorded at once in the *observation booklets* uncorrected, but with a note of the corrections to be made. The calculations, which were made by the various observers quite independently of each other, were made in *figure books* specially destined for that purpose. The results were entered by each observer in the *log-book* and showed to the Commander. The Commander determined the true position, which was then entered in the log-book and initialled by both observers. The ship's log-book contained, in addition to the reckoning and what is prescribed by law, a detailed and continuous account of the work done. This was duplicated into a *copy-log-book*, both books being inspected by the Commander daily. From the log-book and the current observations the most probable course that the ship had followed was plotted on the route charts. The uncorrected echo distances, with a note of the time and particulars, were entered in the *echo sounding books* by the echo leadsmen immediately. The right-hand pages of these books were not printed, being destined for calculation of the half-echo times and corrected echo distances. These calculations and conversions were checked by making random tests. The half-echo times and corrected echo distances were copied out, together with the numbers, dates, times and particulars, into the *echo sounding registers*, all entries being called over. For the construction of the *bottom sections* the distances between the apparent places indicated in the log-book were calculated and with these distances the construction on the route charts was checked; for the construction the corrected echo distances entered in the sounding books were used. For the fair sheets the log-book, sounding registers and route charts were consulted.

The *ordinary meteorological observations* were made by the officer of the watch and entered by him in a rough log-book, from which the log-book proper was filled in, as is usual.

The books and registers required were printed in Holland. For the section sheets we had available drawing paper marked with red lines at 5 cm distance from each other. The lines for the fair sheets had been drawn, for a part, in advance.

Ship's time. When the ship was between 115° and 120° long. East the apparent time of the meridian of 117½° E. was used, and when between 120° and 125° E. the apparent time of the meridian 122½°, and so on. Thus the time used did not differ more than 10 minutes from the apparent time.

The most usually occurring and most important duties on the expedition were allotted to the personnel as follows:

Lt. J. P. H. Perks	Senior Officer. Middle Watch. Reckoning. Fair sheets.
„ L. J. Veldman	Officer of watch. Reckoning. Wireless and electr. apparatuses (incl. echo sounders). Supervision of reduction. Sectional sheets.
„ F. H. M. van Straelen	Officer of watch. Reckoning. Nautical instruments. Route charts. Meteorological log-book and current chart.
„ T. H. Milo	Officer of Watch. Reckoning. Sectional sheets.

(after October 1929)

Second Engineer	T. Veerman	} as Chief Engineer
replaced by do.	H. Gorter	
„ „ „	C. A. Vos	
Lieut.-Surgeon	P. C. Broekhoff	Medical Officer
Lieut.-Paymaster	J. F. Staverman	} as Administrative Officer and Expedition's Treasurer
replaced by do.	S. Groot	
„ „ „	G. Bakker	
Boatswain	C. Mallie	} as Boatswain
replaced by do.	T. P. A. M. Kabel	
replaced by W.O. torpedo-gunner	J. Kater	
W.O. Telegraphist	A. J. Woltering	Chief echo-leadsman. In charge of nautical instruments and upkeep of various machines. Keeper of rough deep-sea chart. Reduction. Entering up echo sounding registers. Stopping for astron. reckoning.
W.O. Artificer	A. W. H. van Bladel	} as instrument-maker
replaced by P.O. do.	C. van Kapel	
P. O. Signalman	C. Becher	} Stopping for astron. reckoning. Wireless station. Reduction.
repl. by W.O. Telegr.	C. P. van Haasteren	
Native P.O. Signaller	Abdoel Madjid.	Reduction; reserve echo-leadsman; stopping for astron. reckoning.

P.O. Fitter	A. C. Geljon	Electrician and reserve echo-leadsman.
P.O. Clerk	A. W. Krielen	Clerical duties. Copy of log-book.
Leading Seaman	D. A. L. Hitz	} Echo sounding; attaching and detaching instruments for sounding and serial observations; calling-over.
„ „	A. Groters	
„ „	W. Woltering	
„ „	G. Stolk	
„ „	J. Marquart	} Asst. analyst for oxygen content
repl. by do.	P. J. Louws	
Leading Seaman	P. Wassenaar	} Asst. analysts for salinity
„ „	D. Onkenhout	

Other members of the crew were: 3 W.O. Engineers, 1 sick-bay attendant, 1 P.O. Carpenter, 1 P.O. Steward, 1 Purser, 1 native boatswain, and further, as average complement, 3 native quarter-masters, 28 native seamen, 18 native engine-room men and 16 native cooks and boys.

At the end of the expedition there were completed or almost completed 17 fair sheets for the deep-sea chart, 50 sectional sheets and 3 meteorological log-books.

c. HEALTH AND FITNESS OF CREW.

When, at the end of July 1929, a start was at last made with the work for which we had been preparing for one to two years, everyone set to work with a vengeance. The work was new to us and we were all keen on it. When we put in at some very nice places — Mamoedjoe, Paleleh — it was therefore more with the intention of catching up arrears in the constructional, drawing and titrating work rather than out of need for a rest. The deep-sea anchor installation was quite in order, and all observations were successful, most interesting results already having been obtained. In a word, the work was proceeding without a hitch and at a good pace.

At Menado we were given a very cordial reception, and we had a delightful trip round the lake of Tondano, this being followed by a visit to Ternate.

However, on the long run through the Ceram, Aroe and Timor seas to Timor-Koepang — a much less interesting part of the archipelago and with hardly any anchoring places — there were signs of fatigue among us, and it was felt that the pace could not be maintained.

Already on our arrival in the Indies I had asked for a fourth officer, and at Koepang Lieutenant Milo came aboard, so that from then onwards it was easier to keep up with the work.

In the first three weeks of the following year the ship was in repair at Soerabaya. Apart from the docking and necessary reconditioning of the ship and engines, the instruments had to be thoroughly overhauled and the reels rewound with new wire, so that everyone was busy the whole day long. Unfortunately, there was no accommodation available ashore, and it was somewhat depressing having to stay on aboard while lying in the yard. Owing to the dry monsoon and the plague of flies, there were many on board suffering from abdominal and throat troubles, which as a matter of fact were commonly prevailing in the whole of Soerabaya. After the repairs had been completed this necessitated our staying on another week on the roads to clear the ship of flies and mosquitoes and to replace sick members of the crew. The consequences of that forced stay at Soerabaya were felt for a long time afterwards, and a month later we had to make for Makassar at full speed to put Doctor Broekhoff into hospital there, whilst also the leader of the expedition had to be left behind owing to illness.

In the course of a speech that I delivered to the crew on the ship being commissioned at Rotterdam, I pointed out the difficulties with which we should be faced on the expedition. I warned them that they were not to imagine that we should experience much particularly remarkable, but that on the contrary the work was likely to become most monotonous, that there would be but little pleasure and that it would mean hard work in a tropical climate. I expressed the hope that they would not lose heart but would devote themselves right to the last to the task they had undertaken.

My idea of what the work would be, was found to be correct, but also the hopes I entertained of the personnel were not falsified.

To many it may seem strange that such a life should be so monotonous, there being so much of interest to see and study, so many beautiful places to be visited. And, indeed, there is much of interest in working out the data *after* the expedition, but not in the collecting of those data. Preliminary conclusions can certainly be drawn, and the chart and sectional sheets sometimes brought surprising news, but then these surprises were spread over a period of 16 months. The country is beautiful, but our work was at sea. At all the places we put in at for victualling we were very well received, but after all most of them were only small places which had not much entertainment to offer.

In June 1930, signs of strain on board became apparent. Indigestion, colds and wounds had more serious consequences than usually follow from such complaints or hurts. The personnel on the whole began to look seedy. This was due to the monotonous life and little variation in the food, but possibly also to lack of fresh water, accompanied by strenuous work for a long time at a stretch. As far as possible fresh vegetables and fruit were taken in and also as much water as possible, and every week at least 36 successive hours were spent at anchor, preferably at a nice quiet spot. Nevertheless, when putting in at Soerabaya for the second time, from the middle of July to the middle of August 1930, it was necessary to send the Europeans to Malang for a fortnight's rest in a cooler climate, and the natives were given a fortnight's leave.

The rest at Malang did a great deal of good, so that the third period could be begun with fresh spirits, and although at the end of the expedition most of the personnel were exhausted, everyone kept up well right to the last and we were able to do more than we had counted upon.

Health and fitness of the crew are of just as much importance as the technical equipment of the ship. For an expedition out for a long time in the tropics it is a difficult matter to keep everyone fit and devoted to the work to be done, and in this, I was ably assisted by the medical officer.

I wish to express here my great appreciation to the personnel who stood beside me. All, without exception, gave of their best.

¹⁾ Victualling was done at Soerabaya, Menado, Ternate, Timor-Koepang, Makassar and Ambon. Further, calls were made at Mamodjoe, Tarakan, Paleh, Chongos bay (near the Sibotoe strait), Kafal (Misool), Boela, Dobo, Wotap (Tanimber), Waingapoe, Seba, the Postillion islands, Bima, the Paternoster islands, Katella (Djampea), Boeton, Vesuvius bay (Soela-Mangoli), the Nenoesa islands, Kaoe bay, Beo, Rioeng (Flores), Toekang-Besi islands, Banda, Strait Lembah, Sopi bay (Morotai), the Boo islands, Leti and Endeh.

Unfortunately we lost two men, both old-stagers, the native stoker War dying on the 30th of April 1930 and the native engine-man Sarbini on the 1st of July 1930.

H. SOME NAUTICAL RESULTS

Although the object of the expedition was not at all to carry out nautical work, nevertheless — apart from the sounding and reckoning — also in that direction some results were attained which I believe to be well worth mentioning.

1) That a ship equipped with an echo sounder can derive benefit from it in deep water just as it can from a hand lead in shallow water is only obvious. But then the proviso is to be made that also a reliable deep-sea chart must be available. The echo sounder certainly gives warning when approaching a shallow, but that alone is not sufficient for safe navigation, as may be seen from the following.

When leaving the Gulf of Boni, course had to be set at night on the Garlarang reef, belonging to the Tiger Islands. The slope of the reef was not sounded in time. The course was followed until, according to dead reckoning, we were in the middle of the 7 mile broad atoll, but then the lead was still showing some thousands of metres depth. There was then nothing else to do but stop the engines and wait for daylight.

When steaming at night south of the Kei Islands, the depths diminished from 1000 to 160 metres, the last soundings decreasing very rapidly, while according to our reckoning we should have been a good way off the 200 metre line. The ship was turned about, and we went back on the same course that we had been following, so as to minimise the risk of running aground in this little navigated area.

Both these cases were not free from danger, notwithstanding our using the echo sounder. A good deep-sea chart, however, would have shown where the ship was, and in what direction we had to go.

The deep-sea chart that we have compiled is a geological-oceanographic chart, not a navigating chart, but that does not alter the fact that in some cases it is useful for navigation. Provided thought is given to the question whether the depth lines are based on sufficient data, with the aid of that chart and the lead one can in many cases determine the position.

As an instance the following case is mentioned. The Lifamatola Strait, nautically, had been only roughly sounded when we contemplated laying a station in that strait at night. We had come from Manipa, where, in the evening, we had had our position properly fixed for the last time, and when we reached this strait we were no longer sure of our position. Consequently we made use of the chart of our own survey and directed the ship to the desired spot with the lead, in which we were entirely successful.

Our work should facilitate a reliable survey for a complete deep-sea chart, and for seeking dangers of doubtful position or such as are of doubtful existence the results of our survey may provide valuable data.

2) The current charts given by Van der Stok already show the great constancy of the monsoon currents, and our observations agreed very well with these charts. Moreover it appeared that, except on the side of the Pacific Ocean and in the narrow straits, the tidal currents are generally of minor importance. Further it appeared that charts for a shorter period and with smaller blocks could quite well be compiled. For such charts there are still very many data that have not been worked out. In this area of strong currents they will be of practical importance for navigation.

3) The typhoons passing over and nearby the Philippines affect the weather in the eastern part of our archipelago north of the equator; they bring unsettled weather with squalls. The approach of typhoons is not always forecasted in time by Manila, owing to there being a large area east of the Philippines without any observing stations; meteorological observations in our archipelago on the Pacific side, may often be in a position to provide important information in time for a weather forecast. For instance, while cruising in those parts we were able to forecast an approaching typhoon three days before a warning was sent out from Manila. The first warning from Manila gave for the position of the typhoon, I believe, 60 miles east of the Philippines, but anyhow the warning was rather late.

A meteorological observation post on the Nenoesa islands or on Morotai, on the ocean side, could be of service not only for shipping outside but also for that inside our archipelago; I have in mind the coastal shipping and the air service, which will undoubtedly grow in importance with development of these parts.

In the south-east of the archipelago, storms passing south will have an effect similar to that of the typhoons in the north, though it seems to me that there the effect is not so great. Nevertheless an observation post on Roti, on the ocean side, will certainly be useful.

APPENDIX No. 1. PROPERTIES OF THE CABLES AND SOUNDING LINES

Cable or Wire	Composition	True breaking strength	Weight in the air	Weight in sea water	Length in one piece	Total length carried	Consumption	Cost price	Manufacturers
Anchor cable stranded steel wire circumf. 3.0—5.0 cm	yarn core ¹⁾ centre $1.9 \times 7 \times 0.7$ cover right-hand lay $15 \times 7 \times 0.7$	Abt. 10 tons ²⁾ at the anchor end	Total 5880 kilos	—	7500 m	7500 m	half-worn	f 7400	G. Kocks A.G., Mülheim
Fishing cable stranded steel wire diameter 12 mm	yarn core centre $1.6 \times 7 \times 0.7$ cover right-hand lay $12 \times 7 \times 0.7$	—	Total 720 kilos	—	1200 m	1200 m	ditto		ditto
Cable for serial observations stranded steel wire diameter 4.0 mm	steel core $7 \times 7 \times 0.45$	1530 kilos	70 kos per 1000 m	57 kilos per 1000 m.	9000 m	18000 m	ditto	f 1215 per 9000 m	Felten & Guillaume A.G., Mülheim
Serial cable stranded aluminium bronze wire diameter 4.4. mm	al. bronze core $7 \times 7 \times 0.48$	800 kilos	82 kos per 1000 m	66 kilos per 1000 m	8000 m	24000 m	16000 m half-worn	f 3345 per 8000 m	ditto
Sounding wire stranded steel wire diameter 1.55 mm	$4 \times 7 \times 0.22$	180 kilos	9.5 kos per 1000 m	7 kilos per 1000 m	4500 m	14500 m	3000 m + 5500 m half-worn	f 300 pre 4500 m	ditto
Sounding wire tin-coated piano wire dia. 1.0 mm	single thread	180 kilos	6.2 kos. per 1000 m	5.4 kos per 1000 m	3300 m	45000 m	22000 m + 11000 half-worn	f 120 per 11000 m	ditto
Sounding wire tin-coated piano wire dia. 0.8 mm	ditto	115 kilos	4 kilos per 1000 m	3.5 kos per 100 m	—	12000 m	1000 m half-worn		ditto

¹⁾ At the anchor end.

²⁾ A spliced joint in the middle broke under a tensile force of 12900 kilos.



DATA OF FAIR SHEETS

Area and scale	Boundaries				Dimensions in mm
	Latitude		Longitude East		
Strait Makassar 1 : 1,000,000	2—40 N	5—20 S	117—0	121—30	884.52 × 500.74
Celebes and Sulu Sea 1 : 1,000,000 . .	0—30 N	8—0 N	117—0	126—0	829.27 × 999.02
Strait Siboetoe 1 : 100,000	4—30 N	5—10 N	119—25	119—55	737.14 × 554.57
Philippines and Sangihe 1 : 1,000,000 .	1—0 N	9—0 N	124—0	130—0	884.58 × 665.32
Emden Deep 1 : 150,000	8—50 N	9—50 N	126—40	127—10	737.28 × 366.14
Molukken Passage, Halmaheira and Ce- ram Sea 1 : 1,000,000	4—0 N	4—0 S	125—0	133—0	884.51 × 890.45
Boeroe Sea 1 : 50,000	0—40 S	4—20 S	124—10	129—30	810.81 × 1186.14
Molukken Sea 1 : 1,000,000	1—0 N	5—0 S	120—0	128—0	663.39 × 889.92
Banda and Timor Sea 1 : 1,000,000 . .	3—0 S	11—0 S	125—0	135—0	884.64 × 1104.82
Goenoeng Api 1 : 50,000	6—32 S	6—46 S	126—30	126—50	516.03 × 737.08
Flores and Savoe Sea 1 : 1,000,000 . .	4—0 S	12—0 S	116—0	126—0	884.68 × 1102.30
Bar South of Roti 1 : 200,000	10—40 S	11—40 S	122—0	123—30	553.03 × 819.11
Strait Dao 1 : 200,000	10—10 S	11—10 S	121—50	123—10	553.00 × 729.40
Strait Savoe 1 : 200,000	9—50 S	11—0 S	120—20	122—0	645.17 × 912.36
Strait Ombai 1 : 500,000	8—0 S	10—0 S	123—0	126—0	442.36 × 659.67
Toekang Besi 1 : 250,000	4—40 S	6—40 S	123—0	125—0	884.60 × 886.13
Bali Sea 1 : 1,000,000	4—0 S	12—0 S	112—0	118—0	884.68 × 661.38

THE DEEP-SEA ANCHORING EQUIPMENT

by

J. P. H. PERKS

Senior Officer

Prior to the Snellius-Expedition, deep-sea anchoring, the main object of which is the carrying out of current observations, had only been performed a few times by other ships. In 1878, an American schooner, the „Blake”, anchored in 4,000 metres of water, after having tested for two years an equipment which included an anchor-cable running via the bowsprit and mast to the after-deck.

The experience gained by these vessels, however, could not serve as preparation and guide for the use of the equipment which the progress of science had placed at our disposal.

In the years 1925—1927, a German Atlantic oceanographic expedition had been fitted out on board the „Meteor” with an anchoring equipment which proved to be very serviceable in practice. It was to be expected however, that the circumstances under which H.M.S. „Willebrord Snellius” would have to anchor in the eastern part of the Netherlands East Indian archipelago would differ in many respects from those of the „Meteor”, for the tropical waters, although generally speaking less affected by atmospheric disturbances would present swifter currents in the numerous straits and passages which form the connections between the enormous basins and troughs. Anchoring at greater depths, which would not simplify the manoeuvre, also had to be reckoned with.

Only a very restricted space was available on board H.M.S. „Willebrord Snellius” for the accommodation of the anchoring equipment. Whereas on the „Meteor”, the anchor cable drum was at a distance of about one-third of the ship's length, 25 metres, from the bow, here the whole equipment was installed at a distance of less than 12 metres from the stern on a small deck, which already held a large steam windlass engine, a skylight, four ventilation shafts, forecastle stoppers, hawse pipes and bollards. Consequently, rollers had to be affixed to lead the anchor cable to the various apparatuses, resulting in a considerable increase in weight.

EQUIPMENT,

On the port side, just behind the top of the stem a frame had been placed in which three rollers were mounted; two long cylindrical rollers stood vertically on either side of a third, lying horizontally behind them. The diameter of the last mentioned roller was smaller in the middle than at the sides. As the cable over the roller changed its direction at an angle of nearly 90° the dimensions had not been taken too small, to avoid too sharp a turn. From this point the cable ran along about 25 cms above the deck all the way; its course inboard, shown in figs. 7, 8 and 9 is explained in the following.

From the stem roller the cable ran along the starboard side through the first disc A1, under the first counting disc B1, over the disc C of the block of the dynamometer D and further under the second counting disc B2 to the clamp E, past the discs A2 and A3 and then under the cable roller to the large roller of the capstan F. After several windings round the large roller the cable, guided by a block L passed on to the top of the cable roller H. Next to this drum on the starboard side was a boat steam engine K, which had to hold off and roll up the wound in cable.

The anchor capstan was provided with a larger roller.

The frames of the vertical counting discs were both equipped for the placing of a revolution

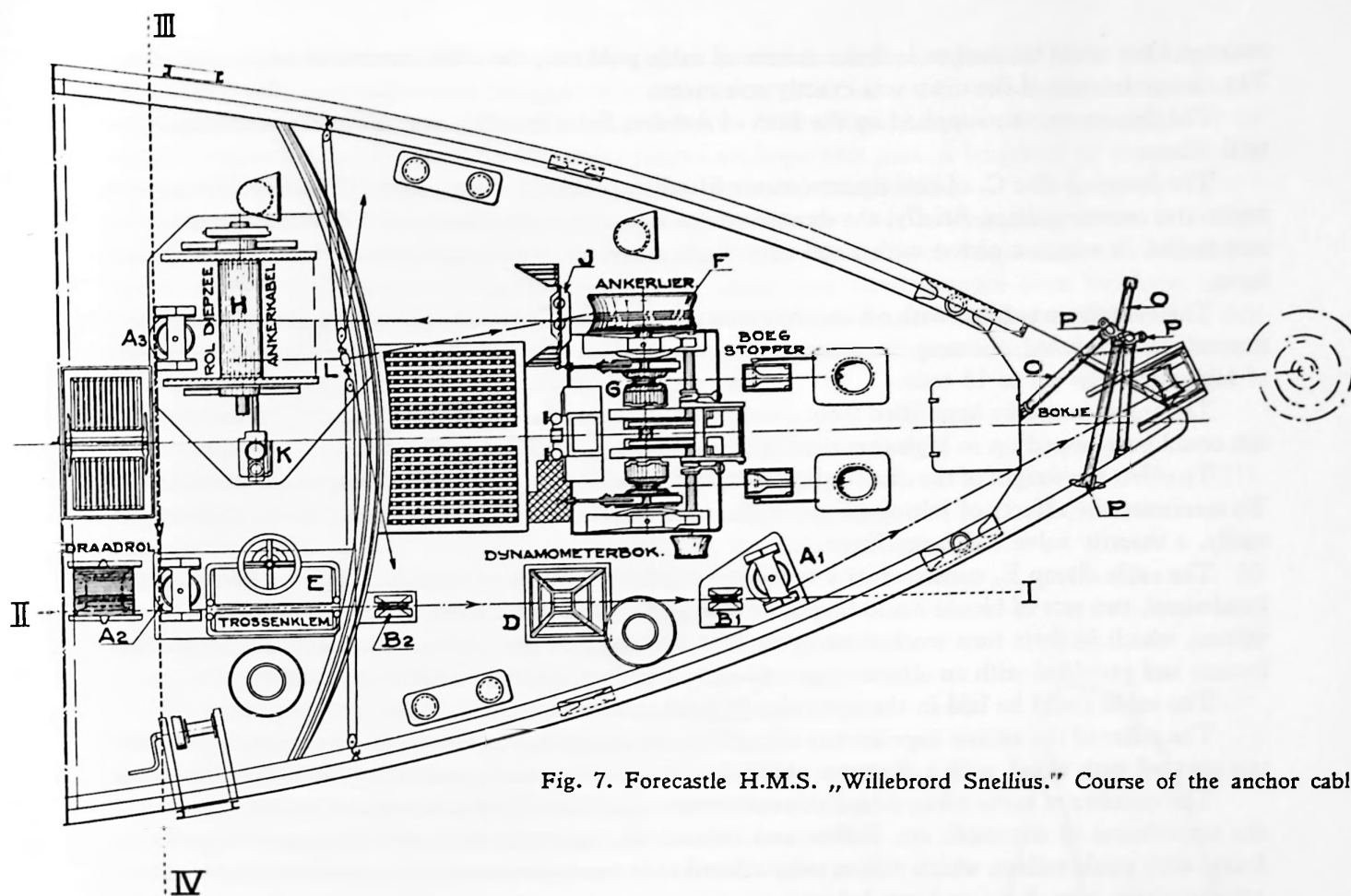


Fig. 7. Forecastle H.M.S. „Willebrord Snellius.” Course of the anchor cable.

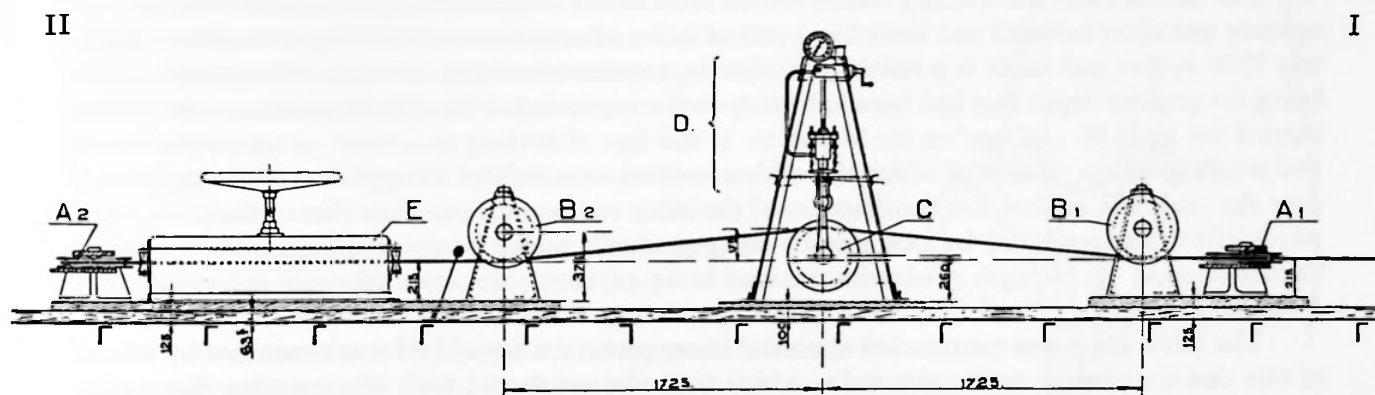


Fig. 8. Section I—II of fig. 7.

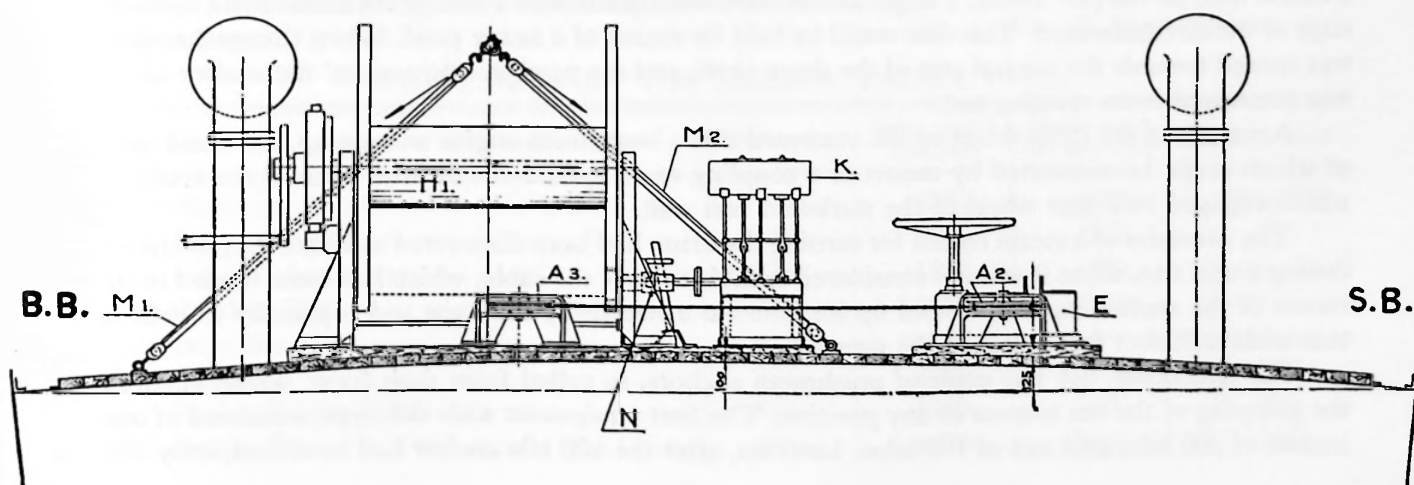


Fig. 9. Section III—IV of fig. 7.

counter. One could be used to indicate metres of cable paid out, the other metres of cable hauled in. The circumference of the discs was exactly one metre.

The dynamometer, supplied by the firm of Amsler, Schaffhausen, was placed between the vertical discs.

The hanging disc C, of this dynamometer lifted the cable up, as it were, 17.5 cm half-way between the counting discs. Briefly, the dynamometer was set up as follows: on a brace a cylinder was suspended, in which a piston with a rod running downwards could move, from which rod the disc hung.

The cylinder was filled with oil and connected by means of a tube with a screw pump to which a manometer was fitted, showing the pressure in the cylinder. The scale graduation showing hundreds of kilograms, ran up to 12 tons.

The pump could be kept filled from a reservoir through a ball valve, by means of which the piston could be pumped up so high that the cable was lifted up 17.5 cm each time.

To offset the weight of the disc itself, four spiral springs were fitted to the bottom of the cylinder. To minimise the effects of jolting on the manometer and to enable the readings to be taken more easily, a throttle valve had been fitted.

The cable clamp E, consisted of a box of particularly heavy construction. By means of a large handwheel, two sets of blocks could be put in motion in it, after transmission by means of shafts and worms, which in their turn worked two very long clamping shoes. These shoes were made of hard bronze and provided with an almost semi-cylindrical groove, through which the cable ran.

The cable could be laid in the open clamp from above.

The roller of the anchor capstan was about 50 cm wide, cylindrical in the middle, smooth, unlined not covered with wood, with a diameter of about 120 cms, but running out shell-shaped at the sides.

The number of turns taken round this roller varied with the depth, the amount of cable paid out, the smoothness of the cable etc. Before and behind this capstan roller, the cable passed a vertical frame with guide rollers, which rollers were affixed to it two by two on slides, which could be moved athwart ships, two above and two below.

The anchor cable was entirely wound on the cable drum, the inner end once pushed through an opening and there fastened and locked in a sort of heavy clamp on one of the side walls. The length was 7500 metres and made it possible to anchor to a maximum depth of about 6500 metres, this being the greatest depth that had been known up to the beginning of the expedition, from a sounding carried out by H.M. „Siboga” in the Moluccas. It was free of kinking as a result of the fact that the two windings of the strands of which the cable consisted were twisted in opposite directions; moreover the cable was conical, i.e. the diameter of the inner end was greater than that of the outer end, which effect was produced by new strands being gradually added to the windings and the use of thicker strands. Its strength grew with the load to be expected; the circumference increased from 3 cm to 5 cm.

The cable drum was constructed of several heavy parts; the actual reel was connected by means of two cast-iron bosses to the side walls, which were also reinforced with ribs running diagonally. Through the reel ran a solid shaft, at the port end of which was a brake disc with a conical seat. Outside this, on the port frame, a larger ratchet disc was affixed with a seat on the inside and a toothed edge at the circumference. This disc could be held by means of a heavy pawl. When the ratchet disc was turned towards the conical seat of the drum shaft, and the pawl was turned, in the anchor cable was prevented from running out.

Across from the cable drum on the starboard side a boat steam engine was set up, the crank axle of which could be connected by means of a coupling to an extended axle with pinion, the teeth of which engaged in a gear wheel of the starboard reel wall.

The necessity of a steam engine for turning the drum had been discovered on board the „Meteor” during a trial trip, when it was not considered feasible to have the cable, which had been hauled in by means of the anchor capstan, wound up for hours at a stretch by the crew and especially to hold it taut with sufficient force clear of the capstan.

For anchoring, use was made of mushroom anchors, so called from their form, which ensured the gripping of the sea bottom in any position. The first equipment with this type, consisted of one anchor of 200 kilos and one of 100 kilos. Later on, after the 100 kilo anchor had been lost, only 200

kilo anchors could be used. This weight may appear small when it is considered that the displacement was nearly 1200 tons and such ships generally make use of 1000 kilo anchors —and in the case of surveying vessels even anchors of 1200 kilos — with heavy chains. Here, however, the great weight of the run-out cable and its resistance in the water played an important part. A length of 16 mm cable (15 fathoms = 27 metres) with swivel served as a fore-runner to the anchors.

To hold the end of the cable, after it had been fastened to anchor or chain, there were three stoppers. For the regular winding up of the cable on the drum, a guide block was set up, which could be drawn to and fro by means of two tackles. In view of the very short distance from the drum to the capstan roller the guiding of the cable appeared to be a difficult matter. It was found, however, that the friction on the capstan roller could be made sufficiently great so that from this roller to the end of the drum the cable did not need to be kept too taut.

The weights of the principal parts were:

Stem rollers	400	Various stoppers	80
Cable drum	1480	Anchor cable	5700
Guide discs	550	Cable clamp.	1000
Capstan roller	1000	Gin of dynamometer	140
Frame with rollers	210	Dynamometer	20
Steam engine	360	Anchors	430
Wooden foundations	400	End chain	180

or a total of about 12 tons.

Fore on the port side, part of the rail was removable, so that a small derrick could be set up there. Three spars 2.5 metres long, and 1 decimetre in diameter had been set up, each provided with a broad 5 cm. thick iron band at the ends. With the aid of some slings and D-shackles any desired construction could be effected. This arrangement instead of a fixed anchor davit gave great satisfaction. When turning in or out had to be stopped temporarily, for instance because the cable had to be attended to, use was made of so-called shears-stoppers, fig. 10 which were introduced generally, both for the dredging cable and for all sorts of sounding wires. For these latter, thinner lines of 0.8 and 0.9 mm they were even the only serviceable ones.

These shears-stoppers consisted of two steel blocks, hinged together. On the two free extremities two steel cables of even length had been affixed, each about 1 metre long, the ends of which were spliced to form one cable, which could then be fastened to a bollard. The sides of the blocks, which were turned towards one another, were provided with semi-circular grooves (which were sometimes again grooved themselves) in which the anchor cable or the sounding wire could be laid. The drawing shows that the stopper was automatically tightened according as the cable exercised greater power.

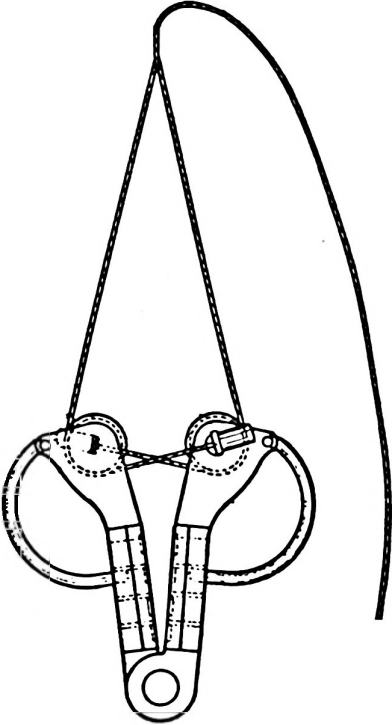


Fig. 10. Shears-stopper.

STATEMENT OF THE ANCHOR TACKLE USED.

No.	Location of the station	Station no.	Echo depth (metres)	Cable paid out (metres)	Anchors used
1.	Makassar Strait	39a	2250	3000	100+200
2.	Sawoe Strait.	135a	1150	1850	
3.	Lifamatola Strait.	253a	1800	2500	
4.	Celebes Sea	308a	4850	6500	
5.	Java Sea	312a	±40	—	ordinary
6.	Angelika	317a	2400	3300	200
7.	Poeloe-Pisang (Obi)	354a	1350	1950	200
8.	Banda Sea	364a	4450	5600	200

MODUS OPERANDI

Anchoring. As a result of the efforts to simplify the method of anchoring to be followed, a mode of operation was at length found, after anchoring at the above mentioned stations, which might be recommendable for future use. The anchor tackle consisted, in the order indicated, of (generally) a 100 kilo anchor, 30 metres of cable, a 200 kilo anchor, 15 fathoms of chain, some ballast and the anchor cable. The use of a swab under the first anchor was dispensed with; the expectation that small fauna living on the sea bed would be entangled in the strands and brought to the surface was not fulfilled.

The end of the anchor cable was attached to the puddening of the small anchor by means of a fisherman's bend which, secured by three plain stoppers, was entirely prepared in advance and was now fastened to the small anchor with a heavy D-shackle. The small anchor was veered out on the anchor cable. Two heavy stoppers were placed on the anchor cable, one about 30 metres from the first anchor, which was fastened to the bowl of the second anchor and a second, which was fastened to the inner end of the end chain. That part of the cable which passed the second anchor was covered to prevent its being damaged. Thus the cable ran from the first anchor to the clamp on the bowl of the second anchor, then loosely along the 15 fathoms of end chain to the second clamp and then as anchor rope inboard. 100 to 50 kilos of ballast were attached to the last point where rope and clamp were made fast. Instead of the 100 kilo anchor, ballast could also be used, but this was not considered to be so good; later on however, it was decided to use ballast, after the impression was obtained from the position of mud and damage in connection with echo depth that the ship was anchored in front of a sweep of the cable, $1\frac{1}{3}$ times the depth being let out even with fairly strong current and wind. Moreover, as already mentioned, a 100 kilo anchor was no longer available.

The second anchor, which had already been hung overboard on the derrick, was veered out with the end chain by means of a sloop winch on the after sloop deck, at the same time as the anchor cable was veered out by means of the anchor capstan; of the latter some metres more than the length of the chain were veered out.

The only delay was in making fast the end of the chain to the second clamp; this did not take long, as the shoulder block with which the chain had been veered out was thrown in not exactly at the end but a few metres from it, so that it could easily be worked with the end of the rope.

The paying out of the anchor cable could now be commenced. The anchor capstan gradually wound the cable off the roller. At the first stations a start was made with four turns round the capstan roller, this number being increased later, but the chance of kinking was so great, in view of the short distance from capstan roller to cable roller, that it was thought better to keep the number of turns constant; this number was fixed at six. Up to 1500 metres the cable would not slip off the shell-shaped side so that a heavy fender had to be constructed and fastened to the base of the capstan and this compelled the cable to glide off towards the cylindrical part of the reel. Moreover, oil and grease were frequently applied at that point.

Later on, the paying out did not require much power and the braking arrangement of the cable roller even had to be used. Owing to the very slight eccentricity of this brake disc, the braking was effected with short jerks which became particularly powerful and dangerous at great depths.

Continual attention had to be paid to the position of the coupling discs of the anchor capstan to prevent sticking. A watch was continually present at one of the two revolution counters to keep the chief officer posted about the length of cable paid out, so that he could decide as to the advisability of manoeuvring. When much cable had been paid out, the steam supply to the capstan was cut off and the cable ran out of its own accord turning the capstan with it. If it had to be stopped for any reason, this was effected by tightening up the brake of the cable roller and immediately afterwards closing the cable clamp as well.

The original construction of this clamp was not sufficiently strong; teeth of crown wheels broke and the cable — which was itself very smooth — slipped through it. Shearstoppers had to be resorted to, two heavy ones behind each other; lengths of thin mooring chain also had to be used, but to make this hold, the cable had to be wrapped in jute.

It was found that although the horizontal stem roller revolved satisfactorily, it showed grooves 2 to 3 mm deep, probably caused by the twisting of the cable. A loud report was heard when the cable fell back into such a groove after having run out when the ship sheered. These jerks on the cable,

as well as those when the cable was eased along the capstan roller, were not absorbed by an accumulator.

At first the ship was slowly manoeuvred by means of the engines before the anchors touched bottom; when, however, it was found at one of the stations that the anchors had fallen practically on top of one another and the cable showed kinks, notwithstanding that the vessel had drifted very much during the anchoring, it was concluded that, owing to the great resistance of the cable in the water, this cable was not dragged along the bottom but more drawn up, this effect being more noticeable according as the depth increased. When the ship was steady, the grounding of the anchors could be observed on the manometer; when she was pitching, the indicator was continually in motion and the moment could not be determined.

When finally the necessary length of cable had been paid out, steam was once more applied to the capstan and the shears hauled over; brake and clamp were then also applied at once and if necessary stoppers added. When anchoring in shallower water it was sufficient to cause the cable to run out more slowly by applying the brake and to stop, after which the clamp could be closed.

Lying at anchor. When the ship was lying at anchor a few more metres of cable were veered out from time to time to prevent its weakening at the comparatively sharp turn over the horizontal stem roller. When anchoring in comparatively shallow water there is more chance of the cable becoming taut, as a result of its lighter weight. If a high swell occurs it may become more necessary than at great depths to decide to veer out more cable.

When the ship is steady but a swift current is running very jerky readings of the manometer may indicate dragging anchors or the stretching of coils in the anchor cable lying on the bottom.

Raising the anchor. When winding in it was found that the boat steam engine could not revolve quickly enough to allow the cable coming from the anchor capstan which was working at full pressure to be wound tightly. This was the principal factor in determining the speed at which the anchor could be raised. Whereas 2000 metres could be veered out per hour when anchoring, the length of cable wound in did not exceed 1600 metres at the commencement and 1800 metres at the end of the manoeuvre.

An adjustable transmission would have been very useful.

When the friction between anchor cable and capstan roller was not sufficiently great, this roller slipped under the cable from time to time, upon which the boat steam engine and the cable roller stopped. The friction was then increased by sprinkling chalk on the roller; when the cable again began to grip the roller great care had to be taken that the cable roller was also revolved at once. Twelve men were then required to set this roller in motion again.

The lubrication of the anchor capstan required a great deal of attention; sometimes, when very much cable was out it was found that running hot could not be prevented by the use of oil and grease, in which case ample quantities of soapy water were applied. On one occasion, when as a result of special circumstances the operation had to be carried out at great speed and the lubricants caught fire, the fire extinguishing line was run over the capstan.

Later on at all the stations work was stopped for five minutes after every hour's winding in.

A watch was now also placed at the revolution counter to give warning of the moment when the anchors were raised; when the ship was not pitching this moment could be observed on the manometer.

During the winding in of the cable at the last station at great depth it was found that many strands of a splice had got loose; they were cut off.

The revolution counter was read when the first mud was noticed on the cable. Sometimes the sand had affected the cable very much; at the third station it appeared as if the ship had lain at anchor in front of a sweep at about 100 metres more than the echo depth.

Great care had to be exercised when the clamp on the cable came up to the stem roller. When this first clamp had been removed the cable and chain (with shoulder block) were wound in at the same time by means of the capstan and boat winch. The 200 kilo anchor was transferred to the derrick with the aid of a Weston tackle and remained hanging there till the end of the weighing manoeuvre. By means of the capstan the light anchor was then brought to the stem roller.

This moment was of interest to the geologist because a denizen of the sea bottom was sometimes found in the hollow of the small anchor, whereas a bottom sampler had not been able to secure anything at the same place on account of the bottom having been worn smooth by the current.

Final remarks. The upkeep of the equipment did not call for a great deal of attention. The cable, which when received and when being wound on to the roller was practically soaked in linseed oil, hardly rusted at all. When being wound in, the cable was dried by two men and before being wound on the roller it was smeared with a mixture of linseed oil and rosin.

Not only was the roller of the anchor capstan chalked to increase the friction but chalk was also rubbed into the vertical counting discs.

The cable had continually to be kept free of the stem; when lying at anchor, if necessary by giving some turns to the rudder or by slowly manoeuvring with the engines.

At none of the anchoring stations did the anchors drag, so that the behaviour of the ship under such circumstances is not known. The ship will probably swing round side-on to the wind only when a strong wind is blowing and not much cable is „out”. The cable itself acts as a heavy drift-anchor; when the wind was blowing 6 to 7 metres per second the ship only veered round when no more than 500 metres were out.

PLATES XII—XVII



Fig. 1. H.M.S. „Willebrord Snellius“, leaving the harbour of den Helder.



Fig. 2. H.M.S. „Willebrord Snellius“, leaving the harbour of den Helder.



Fig. 3. H.M.S. „Willebrord Snellius“, leaving the harbour of den Helder.

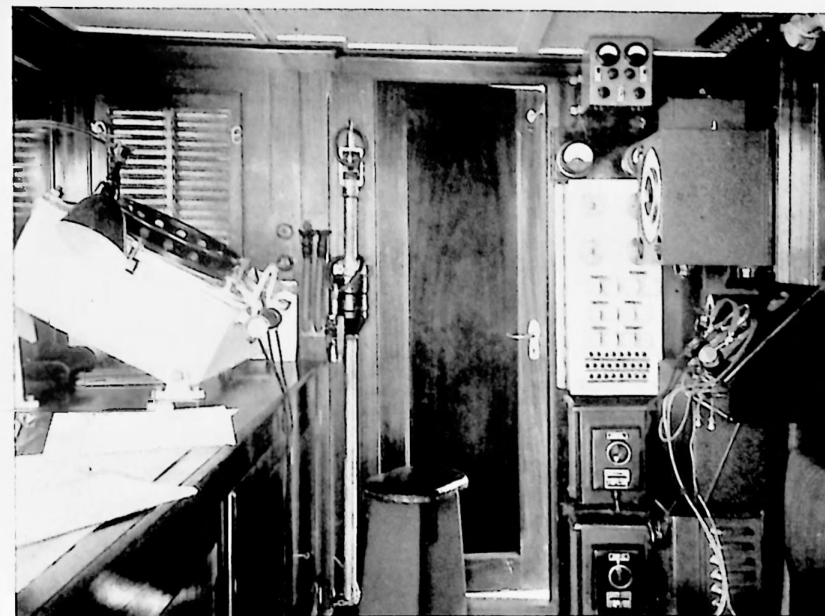


Fig. 4. The chart-room with Hughes sounder, Ekman bottom sampler and Atlas sounder.



Fig. 5. Cabin of the expedition-leader and Mrs. van Riel



Fig. 6. Cabin of captain Pinke.



Fig. 7. Mess-room. Left to right: Dr. Hamaker, Dr. Hardon, Dr. Boelman, Chief engineer Vos, Lieut. paymaster Bakker.

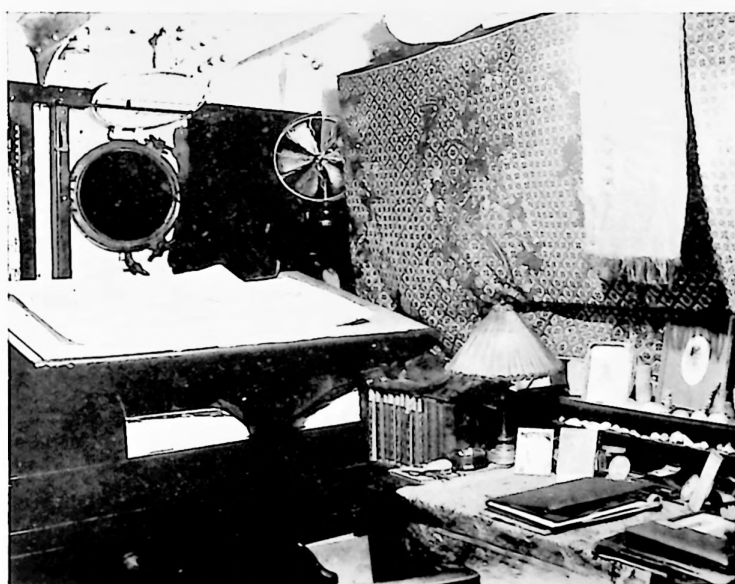


Fig. 8. Cabin of one of the officers.

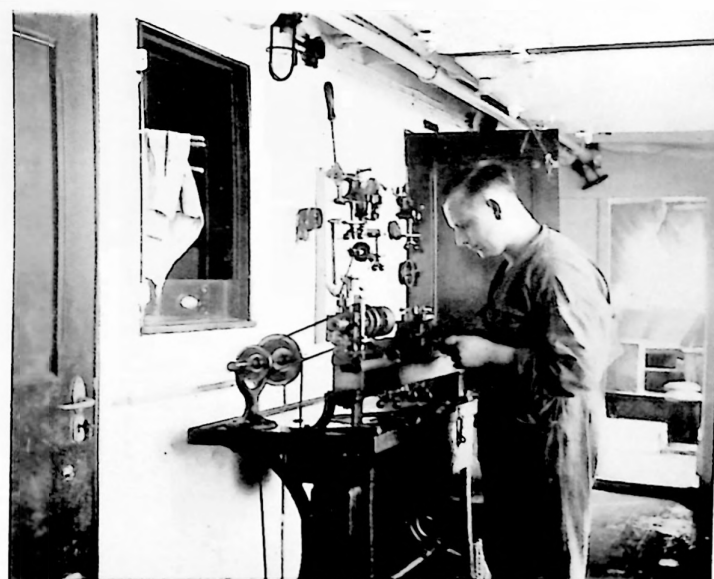


Fig. 9. The instrument-maker's lathe.



Fig. 10. The membranes of the Atlas transmitter.

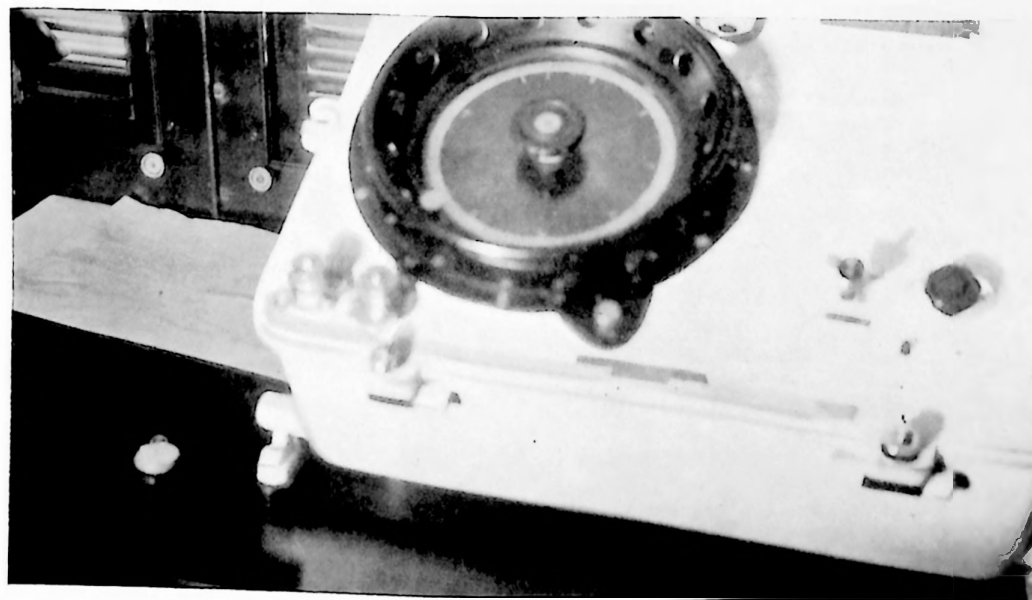


Fig. 12. Hughes recording apparatus in chart-room.

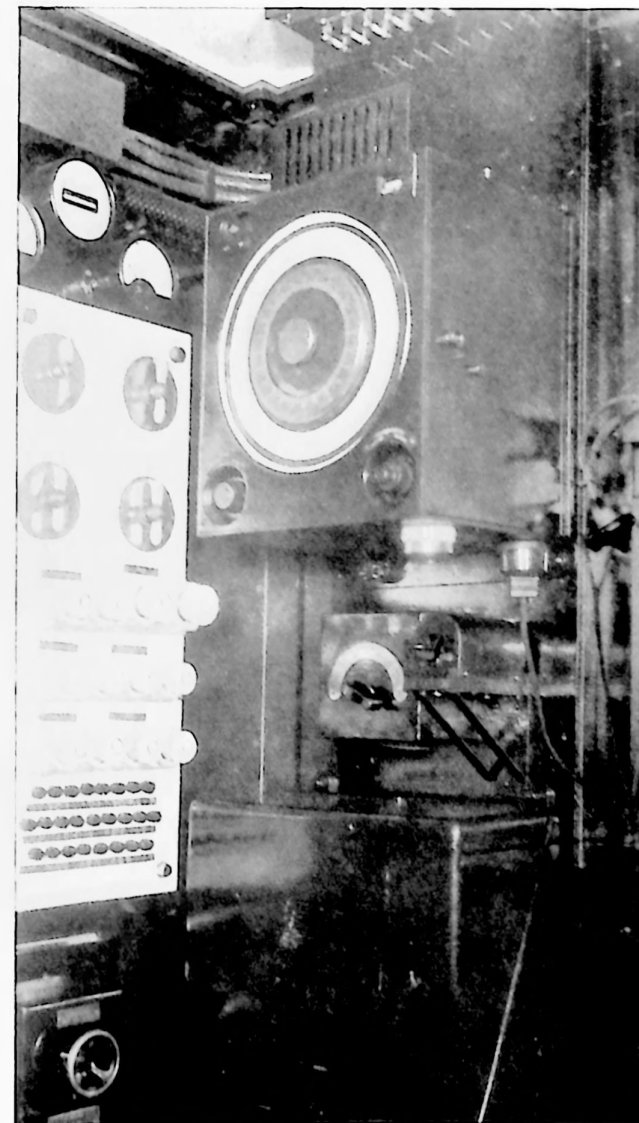


Fig. 11. Atlas recording apparatus in chart-room.



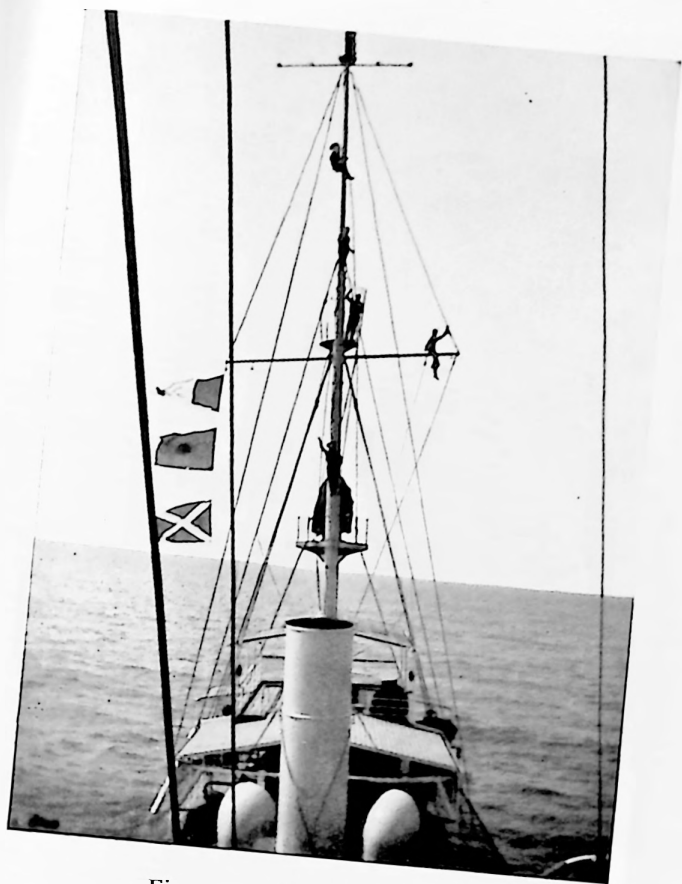


Fig. 13. Lying at anchor.



Fig. 14. Chemical laboratory.



Fig. 15. Testing the drag on the outward voyage.



Fig. 16. Biological laboratory.

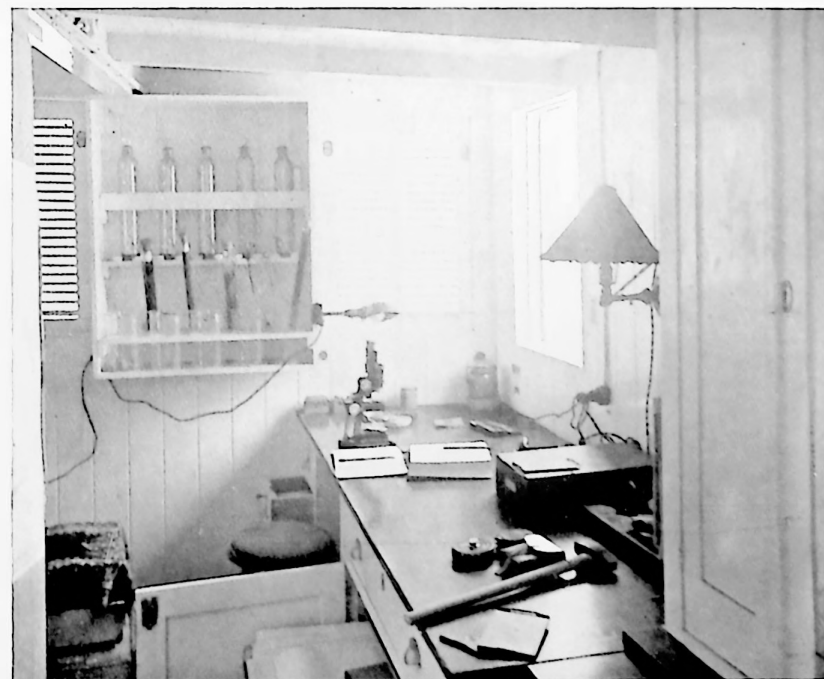


Fig. 17. Geological laboratory.



Fig. 18. Motorboat and two flats left behind for researches ashore.

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN
P. M. VAN RIEL

DIRECTEUR VAN DE FILIAALINRICHTING VAN HET KONINKLIJK
NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË
AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN
F. PINKE

LUITENANT TER ZEE DER 1^e KLASSE

1929—1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET
NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN
HET KONINKLIJK NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP



GEDRUKT DOOR EN TE VERKRIJGEN BIJ
E. J. BRILL — LEIDEN

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE



VOL. I

VOYAGE

CHAPTER III

THE VOYAGE IN THE NETHERLANDS EAST-INDIES

(WITH A LIST OF STATIONS, A LARGE
ROUTE CHART AND 16 DETAIL CHARTS)

BY

P. M. VAN RIEL
(LEADER OF THE EXPEDITION)

1938

TO BE OBTAINED OF THE PRINTERS AND PUBLISHERS
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Those aboard H.M.S. „Willebrord Snellius”

PREFACE

The reader should not expect a thrilling story of the voyage with many particulars concerning the inhabitants of the large number of islands we visited combined with interesting events during the research work. The Netherlands East-Indies have been described so many times by more facile writers and moreover our stay ashore lasted usually only for a short time with the exception of the longer periods passed at Soerabaia.

Undoubtedly cruising in the eastern part of the Archipelago had a great charm, especially in the beginning and for those who visited this beautiful part of the earth for the first time. And for those whose task it was to work up the observations during the voyage in order to be able to send in provisional reports, it gave much satisfaction to be aware of the accumulation of ever-increasing interesting results.

When, however, everybody knew his task the research work became for the greater part of those on board rather monotonous and in the long run the continuous observing, day and night, proved to be more tiring than I had expected beforehand.

Shoulder to shoulder with the Naval personnel the work was completed and a large amount of data was collected during the 16 months that the ship was put at the disposal of the expedition.

The writer's aim is to state in this chapter the way in which this was done, what difficulties were encountered and how they were met with and for what reasons deviations from the original programme occurred. May this be of advantage for future explorers!

For my colleagues-oceanographers I have been too detailed in describing the methods of observing and the instruments used. I did this with the good intention of making things clear also for uninitiated readers and to further the interest for oceanography, especially in my own country.

I am greatly indebted to my former assistant, Mr. L. van Eyck, for his valuable help especially what concerns the composition of the annexed route chart with 16 detail charts. Further I offer my hearty thanks to Mrs. D. Kuenen-Wicksteed who kindly aided me with the translation of chapters I and III.

And finally I want to pay tribute to my wife whose assistance was not restricted to the numerous oxygen-determinations carried out by her on board. Her never failing belief in the success of our research helped me to surmount unforeseen difficulties.

v. R.



CHAPTER III

THE VOYAGE IN THE NETHERLANDS EAST-INDIES

A. GENERAL REMARKS CONCERNING THE RESEARCH

Our research covered an area in extent about as large as the Mediterranean and the Black sea combined. The principal object of the research was the collection of data concerning the physical and chemical properties of the sea water between the surface and the sea floor, the circulation in this space and the configuration and nature of the sea bottom. In Chap. I we have given a full account of the physical, oceanographic, chemical, biological, geological and meteorological research.

All these different subjects are so intricately connected with one another that the results obtained in one direction may have an important bearing upon the problems presented by another branch. Conclusions arrived at concerning the circulation may rest not only upon purely physical-oceanographic observations, they may be also supported by chemical, biological, geological or meteorological results. The composition of the sea floor may be intimately connected with bottom-currents, and chemical properties of the bottom water. A number of examples could be quoted to demonstrate the necessity of continual contact and consultation between the co-workers, so as to attain some provisional results even during the progress of the research.

At the same time it is essential to settle beforehand the method of pursuing the most important activities and the tasks to be allotted to each of the participants. We had a term of about 15 months at our disposal to traverse the whole area, whereby we had to adhere in general to a previously arranged plan by which the area was divided into a number of stations, as shown in plate III, Ch. I. The situation of the stations was so chosen that they lay upon a line perpendicular to the general course of the currents, which could be ascertained in comparatively narrow straits and passages without difficulty. In the vast inland seas, in which nothing could be said beforehand concerning the direction of these currents, the place of the stations was chosen in a line running at about right angles to the coast. Here, and in narrow deep troughs between parallel rows of islands or submarine ridges, the distance between the stations was chosen so that after the first station near the coast on the depth-line of 200 m the next came to lie on the slope and the one following in the deepest part. It was therefore not possible to settle the exact position of the stations beforehand where the configuration of the bottom was not yet sufficiently known. After the oceanographic observations had been made along a line of this kind, we had some idea of the distribution of the various properties of the sea water in a cross-section.

Fig. 2 shows the distribution of the niveaus at which observations were taken at stations 165, 166, 170, 167, 168 and 169, lying in the Flores sea, detail chart 6. Surface and serial observations are indicated by a black dot, bottom observations by a black square. The vertical scale in the sections is exaggerated in order to avoid extremely long and unwieldy drawings. Consequently the bottom gradients are considerably exaggerated also. *At the foot of the drawing, however, the true bottom profile is given.*

This method of working in cross-sections has the following advantages.

1. The depth-lines are cut as far as possible perpendicular; a sequence of soundings obtained in this way makes the drawing of isobaths much easier.

2. From the pressure distribution in the cross-section the current-velocity in any depth may be calculated relative to that at other levels. The direction of these calculated currents, lying perpendicular to the cross-section, will correspond to the probable direction of movement of the water if the section is properly chosen.

By combining the deepest stations in successive cross-sections in a longitudinal section, we see the distribution of the properties of the sea water between surface and bottom in a vertical plane along the axis of troughs or straits. The distribution of these properties gives an indication of the origin of the water in different layers, fig. 14, p. 136.

The observations taken may be divided into:

1. *Observations when under way.* While under way an echo-sounding was taken every quarter of an hour, and when the bottom was uneven at shorter intervals.

Every two hours a sample was collected of the surface water, the temperature of which was determined. A portion of the water hauled up was reserved for the chemical determinations, the officer on duty receiving the numbered bottles needed for the purpose. A card had been added on which the numbers were filled in with the time at which the bottles were to be filled and the position of the ship at the moment when the water sample had been collected. The result of the titrations was entered in the card for the purpose, so that no mistake was possible.

The surface temperature was moreover continually registered by a resistance thermometer placed outside the ship below sea level, plate 6. This registration was frequently tested by temperature determinations with a reversing thermometer when the ship was stationary. On the surface thermogram the date and position of the ship were entered.

When desired, plankton material was collected in a net towed horizontally through the water at a fixed depth at a low speed of the ship (Vol. VI).

The meteorological observations will be detailed later.

2. *Observations at the stations.* Before arriving at a station those concerned were informed in writing at what time the ship was expected to be there, what observations were to be made and in what order they would be carried out.

Op voorm. sleepen planktonnet. In zee, den 23^e Aug '29

Volgende station nr. 52

waarschijnlijk heden te 12^u / morgen te
op 3° 16' N. Breedte en 122° 35' E. Lengte
Te verwachten diepte 5500 m.

WAARNEMINGEN:

1 Draadlading 2 Serie I 3 Serie II
4 Serie III 5 Serie IV 6 Serie Ia
7 Sluiknet 250m 8 9

Parafeeren s.v.p. L. Geol.
Off. v. d. wacht O₂ Biol.
Chef M. K. O₃ Torpm.
Off. v. gezondheid Ch.

Serie IV: 3500, 4000, 4500 en 200 m boven bodem

Fig. 1. Notice to those concerned about the observations to be carried out.

The staff, assisted by the naval personnel had taken care beforehand that everything should be in readiness to begin the observations immediately the ship stopped in the desired position. Moreover the registers were filled in as far as possible beforehand in accordance with a schedule.

In this schedule the niveaus were given at which observations were to be made. According to

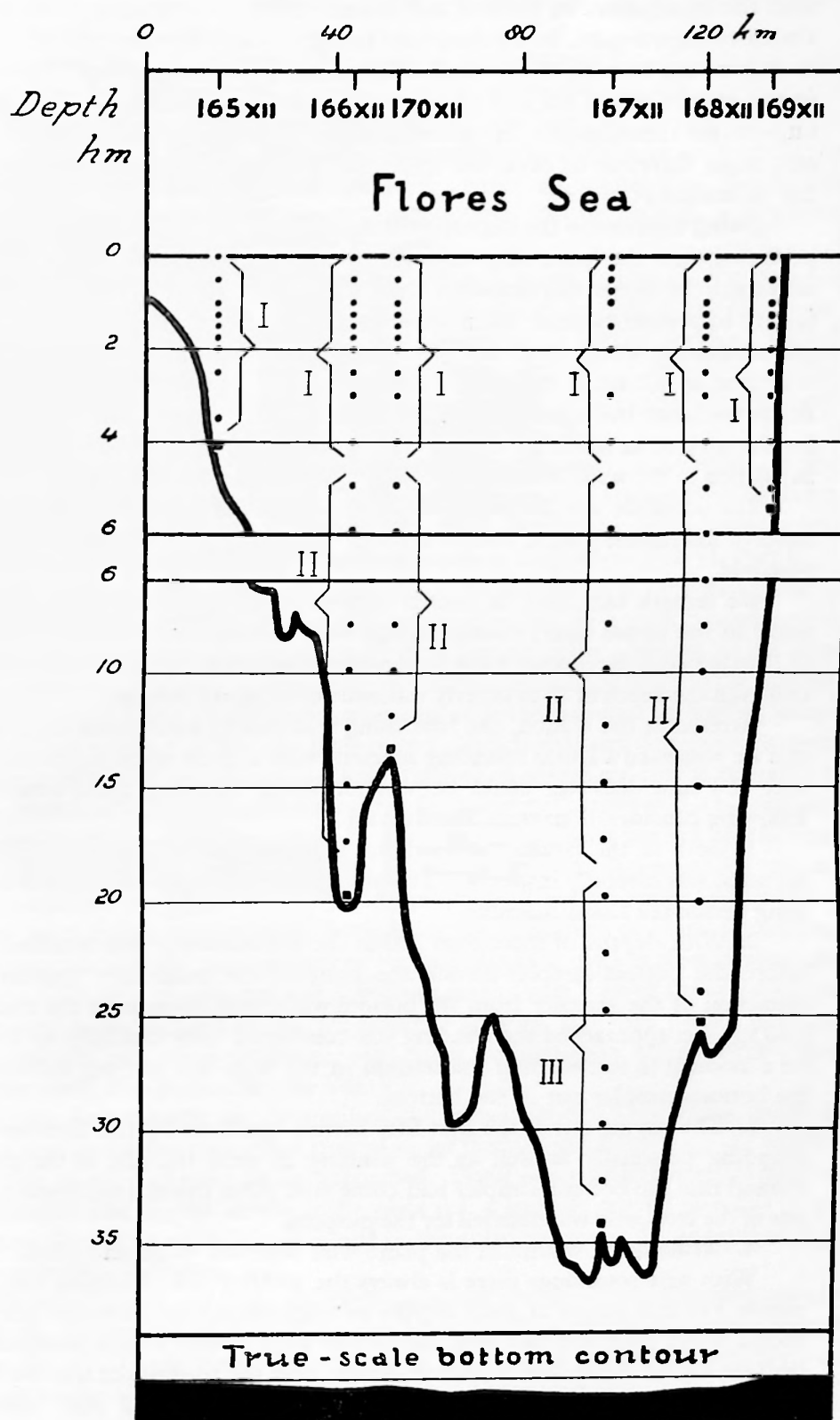


Fig. 2. Distribution of the niveaus at which observations were carried out on a cross-section in the Flores basin. the depth, known from the echo-soundings, 1, 2, 3 or even 4 series were made, fig. 2. With a depth

of fully 5000 m the arrangement was as follows: Series I: 0, 25, 50, 100, 150, 175, 200, 250 and 400 m, series II: 300, 500, 600, 800, 1000, 1250 and 1500 m and series III: 1750, 2000, 2500, 3000, 4000 and 5000 m. For each depth the numbers of the bottles and the thermometers attached to them were entered in the register, with the interval in which the temperature could be measured with this instrument. In the first and second series at two niveaux a second protected thermometer was used. In the third (and fourth) series this occurred as far as possible at each niveau because of the small differences in the temperature. The water bottles in the middle and at the end of every series were provided with a protected and an unprotected thermometer. In cases when the depth was somewhat more than 250 m and could therefore be observed with one series, observations were made also at 125 m instead of 400 m.

Owing to pressure the unprotected thermometer always registers higher than the protected one; the lower they hang the greater the difference in reading. From this difference the depth (thermometer-depth) can be determined. (Vol. II, Part 1). This is very important because the number of metres of wire payed out, read off from the measuring wheel, does not give the depth at which the instrument hangs if the wire is at an incline. If there was a difference between wire-depth and thermometer-depth the latter was usually taken as correct and a proportional correction applied for the niveaux in which no unprotected thermometer hung. The remarks given above in relation to the serial observations apply also to the wire soundings.

The schedule was adhered to as far as possible and as much as seemed desirable. Reserve instruments were always kept in readiness and were also indicated in the schedule.

We remark here that, in coastal regions particularly, the properties of the sea water in the upper layers change rapidly with the depth so that the vertical distance of 25 m between the niveaux must be considered too great. It is therefore to be regretted that even the depth of 25 m latterly was omitted at many stations.

Arrived at the station, the first thing was usually a wire sounding, plate IV. For this we possessed a Lucas sounding machine with a drum upon which 12000 m piano wire of 1 mm diameter could be wound. While directing these observations the following considerations were kept in mind.

1. Both at the paying out and the hauling up of wire any place where a joint occurred was carefully inspected. The position of the joints was marked on a list that hung beside the Lucas machine.
2. With depths of more than 200 m the dynamometer was attached to the wire before the bottom-sampler struck the bottom; the maximum tension during the extraction of the sampler from the bottom was noted. As soon as the breaking strain (180 kg) was approached the winding was conducted very carefully or even stopped for a moment to test whether the tension in the wire was not yet sufficient to draw the bottom-sampler out of the bottom.
3. The paying out of the first fifty meters was done by the director of the wire sounding personally as well as the winding in until the dial of the tension meter showed that the bottom-sampler had come free. After this the work was continued by one of the crew who was detailed for the purpose.
4. While being wound in the piano wire was well dried and oiled.

With wire soundings there is always the greatest risk of loosing valuable instruments. For this reason at great depths an unprotected thermometer was not always added to the protected one with the bottom water bottle. This is, however, a mistake, because a good depth determination drawn from the readings of the two instruments provides a means for checking the accuracy of the echo- and wire soundings. The depths obtained with the latter are almost always too great on account of the incline of the wire. It is endeavoured to make the angle as slight as possible by manoeuvring the ship, but this is not very successful when there is much wind or current. To judge of the accuracy of wire soundings it is advisable to register the incline of the wire during paying out and to measure

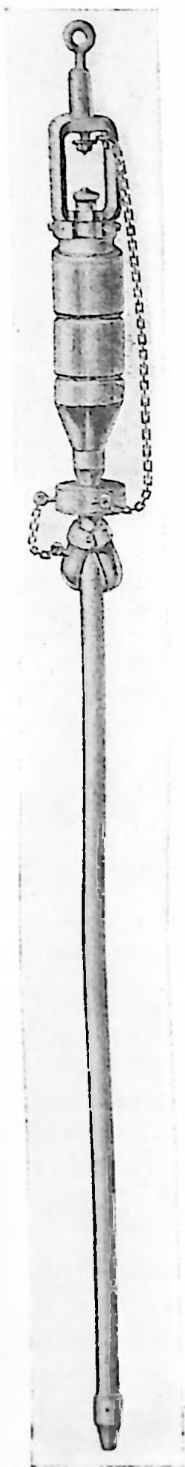


Fig. 3. Ekman bottom-sampler, weighing 32 to 36 kg, diameter tube 20 or 30 mm.

it at the moment when the bottom-sampler is drawn out of the bottom. This applies only to the Ekman-sampler and not to the Monaco-sampler and the Sigsbee lead dropping the ballast weight. It is true that only the angle of that part of the wire, which is above the sea surface, can be measured, but a comparison of the thermometer-depths and the wire-depths has proved, that it is possible to determine an incline correction by means of which the wire-depth can be corrected when there is no thermometer-depth available.

The wire sounding was followed by the serial observations, by which water samples from several niveaus were brought up with one haul and the temperature *in situ* was determined to a hundredth of a degree Celsius. For this purpose we had two large winches on the starboard and port side of the main deck, driven by an electro-motor, plate V. On the drum of the latter was 9000 m stranded steel wire, on the other 8000 m stranded aluminium bronze wire. The breaking strain was 1530 and 800 kg respectively, the diameter 4 and 4.4 mm. The winch with steel wire was used if the depth exceeded 4000 m and for biological catches.

The water bottles with thermometers attached stood ready in the order in which they were to be used, according to the schedule referred to above. As soon as the officer on duty had announced that the observations could begin, the various water bottles provided with thermometers, plate V, and messengers were successively payed out, after a last inspection of the instruments. It is advisable not to pay out the lowest water sampler (in depths greater than 600 m) further than to within 200 m of the depth according to wire or echo-sounding.

After the instruments have hung for a certain time at the niveaus arranged, so that the thermometers have assumed the temperature of the surrounding water a messenger is let down, which slides along the wire and meets the uppermost sampler and turns the successive instruments upside down, so that the water bottles are closed and the temperatures registered (Vol. II, Part 1).

The instruments of one series are taken off in succession after they have been hauled up, the thermometers are read immediately and the instruments put in a rack placed against one of the deck-houses. Here the analysts come to tap off their portion of the contents for the chemical research in the ship's laboratory, plate VI. Here again precautions have been taken to prevent any confusion of water samples by first filling in registers and forms with the numbers of bottles, samplers, etc. The great advantage of reading off the thermometers at once is that any deficiency in their working can be immediately detected, and that the observation when necessary can be repeated before leaving the station either in a following series or separately. Abnormal results in the p_H -determination betray any deficiency in the water bottles. After the first series had been worked off the second and third if necessary followed. After this the first series was repeated to determine the variations that may periodically occur in the properties of the upper layers of the sea water. While the oceanographic observations were being made there was time for the collection of surface plankton, usually two small nets being used at the same time. For vertical plankton catches from deeper layers, the larger tow-net, plate VIII, or a closing net was payed out on the wire rope of the serial winch. The closing net was lowered to the desired depth, for instance 1000 m, and then hauled in to any other level, where it was closed by a metal messenger sent down the wire rope. Occasionally a plankton-catcher or dredge was used. For particulars see Vol. VI.

During the first months we determined the transparency of the water, while at the station, by means of a round white enamelled iron plate let down horizontally into the water and noting at what depth this could no longer be distinguished. These observations were stopped as their utility seemed doubtful. The depths at which the plate could be seen proved to differ very greatly when observed from the sunny or the shadow side of the ship; moreover the amount of clouds proved to exercise considerable influence also.

After the temperature readings had been corrected and the chemical properties of the sea water determined, the results, together with the two-hourly surface observations were entered in the surface register, the serial and bottom observations in a general register, while particulars concerning the bottom observations were entered as well in a separate wire sounding register. Copies of all these results were sent to Holland at the end of each track, as a precaution against the possible loss of the original notes made on board.

Meteorological Observations. (Vol. III). These were made both while under way and at the stations. The officer on duty kept the ordinary official meteorological log concerning surface current,

pressure, wind, temperature of air and surface water, clouds, state of the sea and visibility which were noted down every two or four hours together with some special remarks and the position of the ship. Moreover I had established a complete meteorological station on the ship, so that records of air pressure, temperature, relative humidity and rainfall could be made. The meteorological screen was of the ordinary design and suspended on the compass deck about 9 m above sea level, plate XIX.

On all diagrams the date and the ship's position at noon were entered. So as to be able to compare the registrations and the visual observations, it is essential that the clockwork of the instruments should mark the time accurately, or that the moment of comparison should be marked on the diagram.

Local ship's time was used, i.e. the apparent time for zones of 5° longitude. For instance the apparent time for the meridian of 122° 5 East was used for the zone lying between 120° and 125° East.

The rainfall was registered by a Hellmann rain-gauge, plate XIX, and controlled by means of a common rain-gauge which was emptied at the end of each watch (4 hours). The direction and velocity of the wind was not only estimated by the officer on duty but also measured by a wind vane and hand anemometer. A comparison of the double set of data concerning air temperature and wind enabled us to estimate the accuracy of the ship's observations.

Both while underway and while lying at a station radiation measurements and estimations of the blue of the sky were carried out, if the weather conditions were favourable, plate XXVIII. This was generally done at noon, while in the morning and afternoon a good number of data were collected also. The radiation measurements and those of air temperature and humidity were noted in separate registers. The anemometer and rainfall observations were inserted in the meteorological log, kept by the officer on duty.

Particulars of the activities at the anchor-stations follow below in the description of the various tracks. The observations for fixing the ship's position, those for the meteorological log and the echo-soundings were the duty of the naval personnel under the guidance of Commander Pinke. The other observations were made under the guidance of the staff, assisted by the crew.

If the geologist and biologist were absent from the ship engaged upon their research on shore, or when help was needed for the execution of observations at an anchor-station, we never applied in vain for the co-operation of the commander and officers. Without slighting the help given by others, I should like to make especial mention of the efforts in this respect of warrant-officer A. J. Woltering.

For the plotting of the track of the ship and the insertion of the echo-soundings on working charts and fair sheets I refer to Vol. II, Part 2, Ch. II, p. 6 and 7. In Ch. II of this volume further details are supplied concerning the participation of the marine personnel in the work of the expedition.

The following are the particulars of the duties entrusted to the members of the staff. Before the commencement of each track, the work to be done according to the scheme I had laid down in Holland was elaborated in detail. With the known speed of the ship, the number of hours was calculated required for the completion of the track. For every station, the place of which was approximately decided, the number of hours needed for carrying out our observations was calculated, on the basis of the depths marked in the existing chart. For Sundays which often included putting the geologist and biologist on shore for their observations, a fixed number of days per month were subtracted, as well as for loading of fuel at the oil stations. Finally a few days had to be kept in reserve for sounding the sills between the various basins and for detailed sounding work in those parts where the bottom configuration might show marked deviations from Tydeman's depth chart.

The construction of a programme of this kind demands much time, but it has the great merit that every day it can be seen whether the work is behind hand, or whether there is time for extra observations to be made. If it is behind hand it is better to miss out one whole station or section rather than carry out two projected ones incompletely.

After the programme had been made up for the following month, consultation was held with Commander Pinke over the feasibility of carrying it out. In the course of the track the work for a particular number of stations was discussed with the members of the staff.

As far as was possible the results of the oceanographic observations were worked out provisionally in co-operation with Dr. Hardon and Dr. Hamaker. At the same time provisional depth contours were drawn on the basis of the echo-soundings. This enabled Kuenen and me to take earlier results

into consideration on the further research and to communicate them in the reports which were sent to Holland every two months. Finally observations of the sun's radiation were my work.

Prof. Boschma, biologist, superintended the biological research on board and undertook a provisional examining and sorting of the catches and the transport to Holland. At the various anchorages in the neighbourhood of the coast or coral reefs his research extended to the fauna there. When he was absent from board for a more extensive research on a group of islands the ship's medical officer was kind enough to undertake the collection of plankton (see Chap. IV).

Dr. Kuenen, geologist, superintended the wire soundings and treated the bottom samples, plate XXVIII, which were provisionally examined and sent to Holland at fixed intervals with the geological material collected ashore and on the reefs. His notes concerning the probable course of the depth-lines founded upon geological considerations were of much value for drawing the representation of the bottom formation as given by the fair sheets drawn by Lieutenant Perks and by the bathymetrical charts found in Vol. II, Part 2, Chap. II. For his research on shore we refer to Chap. IV. In co-operation with Dr. Hamaker he prepared a film during the cruise and made an excellent collection of photographs.

Dr. Boelman, chemist, carried out the chemical determinations of the water samples as regards the contents of p_H , phosphates, H_2S and the alkalinity. He noted these results with those for temperature, salinity and oxygen in a general register.

Dr. Hardon, chemist, was responsible for the determination of salinity and oxygen. He took it in terms with Dr. Hamaker to superintend the serial and current observations and the correction of the readings of the reversing thermometers. He calculated the salinity and oxygen contents from the titrations carried out by the analysts, noted them in the books provided for the purpose and worked up these data, as far as he had time, for producing provisional results.

Dr. Hamaker, physicist, with Dr. Hardon, conducted the serial and current observations, and corrected the readings of the reversing thermometers. He was responsible for the maintenance and good order of the meteorological and oceanographic instruments, assisted by the naval mechanic (torpedo petty-officer). It was his duty to make the visual observations for checking the barograph, hygrograph and thermograph and the registration of surface temperature. He superintended the current measurements at the anchor-stations and assisted the leader in a provisional working up of these data and those concerning temperature and salinity. Many photographs have been taken by him.

Mrs. van Riel took a great part in the determination of the oxygen contents and rendered me much assistance in carrying out my administrative activities.

B. WEATHER CONDITIONS

The effects of the hot damp climate in the area of research which made great demands upon the strength and endurance of the inmates of the ship was amply compensated for by the usually favourable weather conditions and the quiet state of the sea during the greater part of the year. While the oceanographer in the open sea at high latitudes and in the areas where tropical cyclones are common, always runs the risk of losing valuable instruments by the rough weather, in the quiet inland seas there is little danger of this sort and only a small number of reserve instruments are necessary, with the exception of those used with the wire soundings.

At the same time some allowance must be made for the conditions of weather and sea in the various areas to be traversed when, as in our case, the expedition extends over the whole eastern part of the Archipelago and occupies a whole year or more.

In Chap. I, on p. 8, we have said something about the weather conditions, referring to the publications by Van der Stok and Braak. Generally speaking during the months of June to August the east monsoon prevails, in which the moderate to strong breeze in the Banda sea decreases towards the west, while in the straits east and west of the island of Celebes and in the Celebes sea the wind, following a more southerly direction, is usually light on the average.

In the months of December to February the more squally west monsoon prevails, during which the breeze south of 4° S. is on an average less strong than in the east monsoon, while the western direction becomes more N.W.-ly towards the east. North of the above parallel the wind is more northerly to N.E.-ly while the strength rises to 3 to 5 Beaufort-scale.

During the change of the monsoon the weather over the whole area is generally speaking quiet, especially in the months of October—November and March–April. In the south-easterly part of the Banda sea the east monsoon can blow fairly strong even in May and September while it is pretty quiet in the rest of the field of research.

Tropical cyclones occur only seldom in the Archipelago, and principally in April in the neighbourhood of the island of Timor. As the research was to be extended into the Pacific Ocean to about 10° N. the possibility of typhoons in this part had to be taken into consideration in settling the route.

If the choice is free and a vessel at our disposal for some 15 months, the best time to start is March or October as this will enable us to take advantage of the favourable weather conditions during three changes of the monsoon.

Owing to circumstances, our departure from Soerabaia fell in the middle of the east monsoon at a time when a strong south-easterly wind is blowing in the Banda sea, accompanied by a much disturbed sea surface. It was therefore indicated that our direction should not be eastwards, but that we should work towards the north, through Makassar strait, keeping to our previously arranged plan in general lines, plate III, Ch. I.

C. FIRST CRUISE JULY 27th—DEC. 29th 1929

As the expeditionary vessel had to be in Soerabaia in January and August 1930 for a general overhaul, and our research would take about 15 months, our time was divided into three cruises, each of which was again divided into tracks of about a month's duration. About six days of this was usually spent at some suitable place, Makassar, Menado, Ternate, Ambon or Koepang. Fuel was taken in at the filling stations Tarakan on the east coast of Borneo and Boela on the north-east coast of Ceram. Thanks to the co-operation of the Naval Department at Batavia, one time, when both these filling stations were outside our route, we were able to fill up at Ternate, to which the fuel was brought in drums. This method of conveying oil is very costly and filling from drums a very lengthy process.

The account of the various tracks should be followed by the text figures and on the accompanying route map, scale 1 : 3.250.000 with 16 detail charts ¹⁾ drawn on a larger scale for those parts where the large route map would not be clear. The maps, drawn at my direction by my assistant, Mr. L. van Eyck, are based upon the ship's log and the charts, on which the track of the ship was traced by Lieut. Van Straelen during the research.

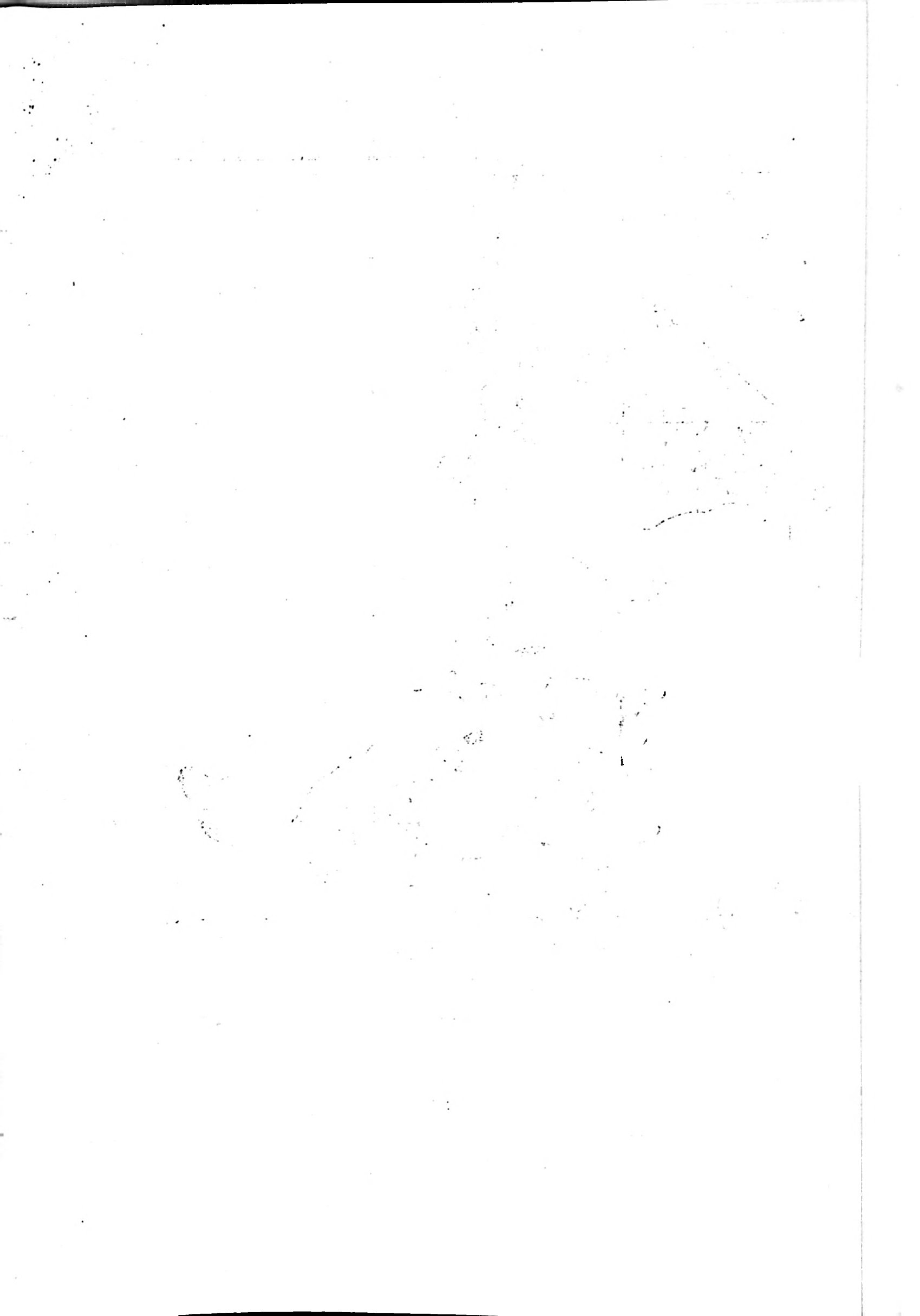
Names of island groups, inland seas etc. are given their Dutch names in the Netherlands Archipelago. The names of places are taken from the Netherlands charts, as well as the 200 m line, the only depth contour drawn on the chart.

On the route chart, the ordinary stations, anchor-stations etc. are marked in different ways as given under „Explanations” on the large chart. The first station is numbered 25 following on to the 24 stations on the outward voyage. In cases of strong surface current the drifting of the ship during observations at one station can be seen on the chart. If more than one determination had been made for the position of the ship the mean was taken.

On p.p. 145—161 the list of stations will be found; an *a* is added to the station numbers there and those on the chart when it was an anchor-station, an *l* when only a wire sounding was made and a *z* when only biological observations were carried out. One station is marked with a *b* when the ship had drifted too far after the anchor was weighed and a second determination of the ship's position had to be made (364 *b*). Column 3 and 7 give approximately the moment at which the wire was hauled up if it was a sounding, or when the uppermost water sampler of the various series was reversed. The last but one column gives the commencement and the termination of the station, the last one the depth in metres; the position of the ship was determined by astronomical observations, bearings of conspicuous points ashore, or by dead-reckoning. Where two places are given, these belong to the beginning and the end of an ordinary station. For anchor-stations only the mean position is given.

On p.p. 161—162 the positions that the anchored ship successively took up according to observations are given; for calculating the mean position no use was made of the results of astronomical observations that had not been made at about the same time. These are marked by an asterisk.

¹⁾ The scale printed on detail charts 1 and 4 should be 1 : 1.500.000 instead of 1 : 500.000. Station 45 on the large chart should be 45 *l*.



REPRESENTATION OF THE PRINCIPAL BASINS AND TROUGHS. BELOW THE ROMAN FIGURES HAVE BEEN PRINTED THE GREATEST DEPTH RECORDED IN THE BASIN AND THE DEPTH OF ITS DEEPEST ENTRANCE. THE ARROWS SHOW THE DIRECTION OF THE FLOW OF THE BOTTOM WATER ORIGINATING FROM THE CHINA SEA, THE PACIFIC OCEAN AND THE INDIAN OCEAN.

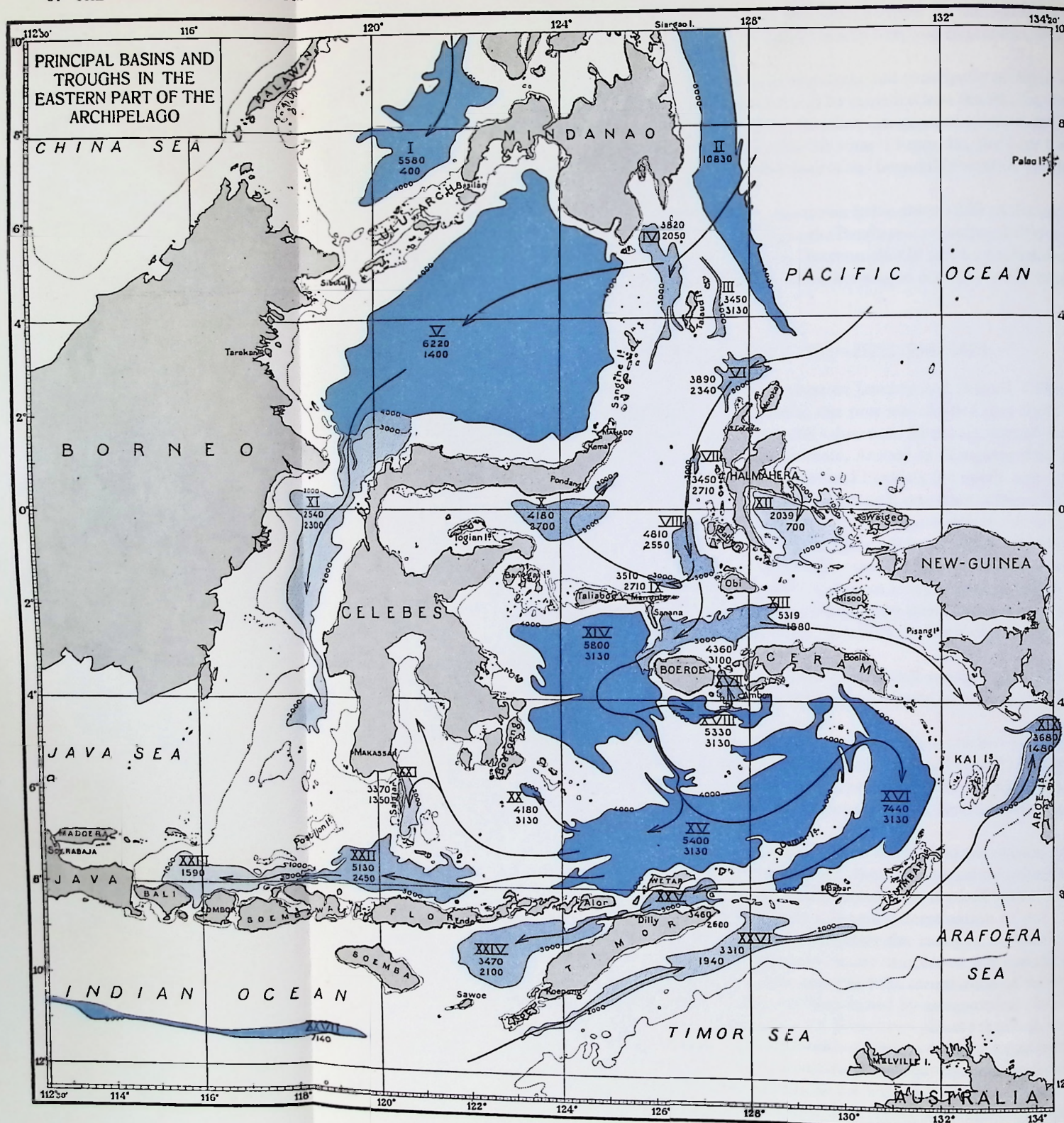


Fig. 4

I Sulu basin, II Mindanao trough, III Talaud trough, IV Sangihe trough, V Celebes basin, VI Morotai basin, VII Ternate trough, VIII Batjan basin, IX Mangole basin, X Gorontalo basin, XI Makassar trough, XII Halmahera basin, XIII Boeroe basin, XIV Northern Banda basin, XV Southern Banda basin, XVI Weber deep, XVII Manipa basin, XVIII Ambalaoe basin, XIX Aroe basin, XX Boetoeng trough, XXI Salajar trough, XXII Flores basin, XXIII Bali basin, XXIV Sawoe basin, XXV Wetar basin, XXVI Timor trough, XXVII Java trough.

a. FIRST TRACK, SOERABAIA-MENADO. JULY 27th-AUG. 25th, STATIONS 25-55.

The photograph printed at the beginning of this chapter, plate XVIII, shows the large number of persons who travelled aboard the ship. Ch. II gives an account of the naval officers and crew. The scientific staff consisted of Mr. P. M. van Riel, leader of the expedition; Dr. A. B. Boelman, chemist; Prof. Dr. H. Boschma, biologist; Dr. H. C. Hamaker, physicist; Dr. H. J. Hardon, chemist; and Dr. Ph. H. Kuenen, geologist, plate XIX. As assistant and draughtsman for the leader Mr. Tampanawas¹⁾ was taken on board and as assistant for the biologist and geologist the „mantris” Erie and Kartodiar-djo. And finally we should mention the second woman on board, Mrs. Van Riel's ayha (Javanese servant) Djiem.

After passing the lightship of the Western Entrance on July 27th we entered the shallow Java sea, where van Weel in former years (Ch. I, bibliography 3) had collected a large number of observations of temperature and salinity. The stations 25 to 28 on the Soenda-shelf formed the introduction to the first of the three cross-sections in Makassar strait. The narrow trough lying here between Borneo and Celebes has a greatest depth of 2540 m and is separated from the Celebes sea by a slight rise of the sea floor in the north to a depth of 2300 m while on the south side the water may enter to a depth of at most 650 m.

In figure 4 a general view has been given of the most important basins and troughs based on the echo-soundings of the „Snellius”.

At first the observations did not run very smoothly. When at station 25 the Ekman bottom-sampler with the water bottle fixed above it were hauled up, it appeared that the apparatus for closing the lower part of the tube of the sampler had not worked and that the thermometer frame with one reversing thermometer which was attached to the water bottle had disappeared. At st. 27 after hauling up, the Monaco-sampler proved not to be closed, but the instrument still contained a little clay.

The stations 29—32 formed the first of four projected cross-sections in the Makassar strait, and here we began with the first deep stations. These cross-sections run from the depth-line of 200 m on the west side to the same depth on the east side of the fairway, or terminate there in great depth when the coast is steep. July 30th was an unlucky day; at night we lost a vertical closing net at st. 30 and at the following station 31 the 4-liter water bottle was hauled up against the measuring wheel so that the wire snapped and the costly instrument with thermometer was lost. During the third series of this station the messenger stuck at a depth of about 12 m on one of the 49 strands of the wire which had come loose owing to a fault in the construction. This loose strand was removed without damaging the wire, after which the series was repeated.

As the deep stations followed in quick succession and the analysts had not yet got accustomed to the routine work the number of water samples to be examined in the laboratory became so great that an anchorage had to be sought to catch up with the work and to make a critical examination of the results obtained. If we had gone on in the way we had begun it would have made altogether too great demands upon Boelman, Hardon and Hamaker.

This most desirable break in the work, which had been counted upon in the programme of the first track became necessary for other reasons. According to a wireless message the surgeon of the s.s. „Sibayak” had died of small-pox. At the order of the Vice-Admiral in Batavia we were obliged to steam to Makassar, there to wait further instructions, as our Chief Engineer, Lieutenant Gorter, had been in contact with the sufferer.

The same evening being anchored in the Hoven Entrance on our way to the roads of Makassar the doctor began by inoculating various of the crew who had not had it done lately.

On July 31th the anchor was weighed at 6 a.m. and in the same morning we anchored in the roads of Makassar, flying the yellow flag, plates XX and XXII. The fear that the ship would have to remain here for some time and that in the laboratory there would be a dearth of water samples instead of an excess, fortunately proved unfounded and the expedition work could be taken up again on Aug. 1st. The Chief Engineer was left behind at Makassar in observation.

The pause at Makassar was made good use of; the belated titrations were almost made up, while several consultations were held in connection with the experience of the last few days, and with regard to the future activities. It was obvious that the number of water samples taken in one day

¹⁾ Later on replaced by Mas Soeprapto.

must be limited. An increase of the vertical distance between the samplers was not desirable, so that it was better to decrease the number of stations. On the other hand the crew who were told off for chlorine and oxygen titrations could be relieved from the watch and ship's duties. Accurate results from the titrations can only be expected if after a fatiguing day's work the analysts can have a good night's rest. Moreover a continual interruption of the exigent routine work does not improve it. The size of the laboratory did not allow of more analysts being set to work.

The meteorological observations for checking the registrations were temporarily stopped and the radiation observations made only at noon, with occasional observations in the fore- and afternoon, when circumstances were particularly favourable. When the sun's altitude was less than 50° it was often difficult to obtain an entirely free space for setting up the apparatus to carry out the observations.

The stations 31, 32 and 33 were worked off in succession. At the last station a vertical closing net was either payed out too rapidly or the weight fastened under the net was not heavy enough, so that the net descended more slowly than the wire rope of the serial winch and kinks were formed in the bottom part of the rope. The messenger that was sent down along the rope to close the net stuck on the kinks. When hauled up a confused mass of rope with the messenger hit against the measuring wheel so that the wire broke off.

On the 2nd cross-section where the trough between the depth contours of 200 m is very narrow, we experienced an extremely strong southerly current of about 3 sea miles per hour, which interfered with the observations. After the wire sounding and each serial observation the ship was found to have drifted some distance so that we must constantly steam north again to find the original spot for the following observations. This was hardly feasible at night or even in daytime, when working far from the coast, so that there is no security that all observations have been made at the same spot. Moreover when drifting to a shallower part, there is danger of damage or loss of instruments suspended at different niveaux. It occurred more than once, that after a wire sounding of 3000 m for instance, the number of the water bottles had to be changed in the third series as according to the echo-soundings the depth had considerably decreased.

But even when paying out the instruments and during the time necessary for the thermometers to acquire the temperature of the surrounding water, the ship could not be kept in the same position. This was very apparent in the narrowest part of the trough near Mamoejdje, where the above mentioned strong southerly current was met with. Abeam on starboard we had two points ashore by which the ship could be kept at the original spot, by slowly steaming ahead in a northerly direction. While doing this and lowering the water bottles the wire rope inclined considerably astern and it was necessary to let the ship drift to the south in order to keep the wire perpendicular. From this it is evident that, when there is a surface current, it is impossible to both keep the wire perpendicular and to remain at the same spot.

The continual steaming back at the stations prevented the second section from being finished off before the end of the week and station 36 had to be postponed. On Aug. 4th (Sunday) we anchored at 8 a.m. in the bay of Mamoejdje, where a day of well earned rest was allowed to those on board. This was certainly needed, especially by the analysts who had been working every day and even at night had taken it in turns to draw off the water samples, a piece of work at which up to now Boelman had always been present. As the number of water samples that were waiting in the laboratory to be tested for chlorine was very great, we lay at Mamoejdje for Aug. 5th to catch up with the work. This gave Kuenen and Boschma an opportunity for research on shore.

Mamoejdje is only a small and poor native village. On coming ashore we did not expect to find anything but natives, but we suddenly beheld a young Netherlander, who turned out to be the son of the military commander of a native detachment, who together with the medical officer comprised the European population.

The weather conditions were at first very favourable, cool with a temperature of 25.5 to 28.5°C . The direction of the wind was changeable with slight to moderate breezes. Later on the wind rose somewhat, especially at night, so that the sea became rather disturbed.

We were now, according to my calculations, $1\frac{1}{2}$ day behindhand with our work, so I decided to omit the 4th cross-section in the northern entrance to the strait. It is better to curtail the number of stations, than the number of observations at one station. After we had left Mamoejdje in the night of Aug. 6th, we first carried out st. 36 and then the 3rd cross-section, stations 37—40. After this an

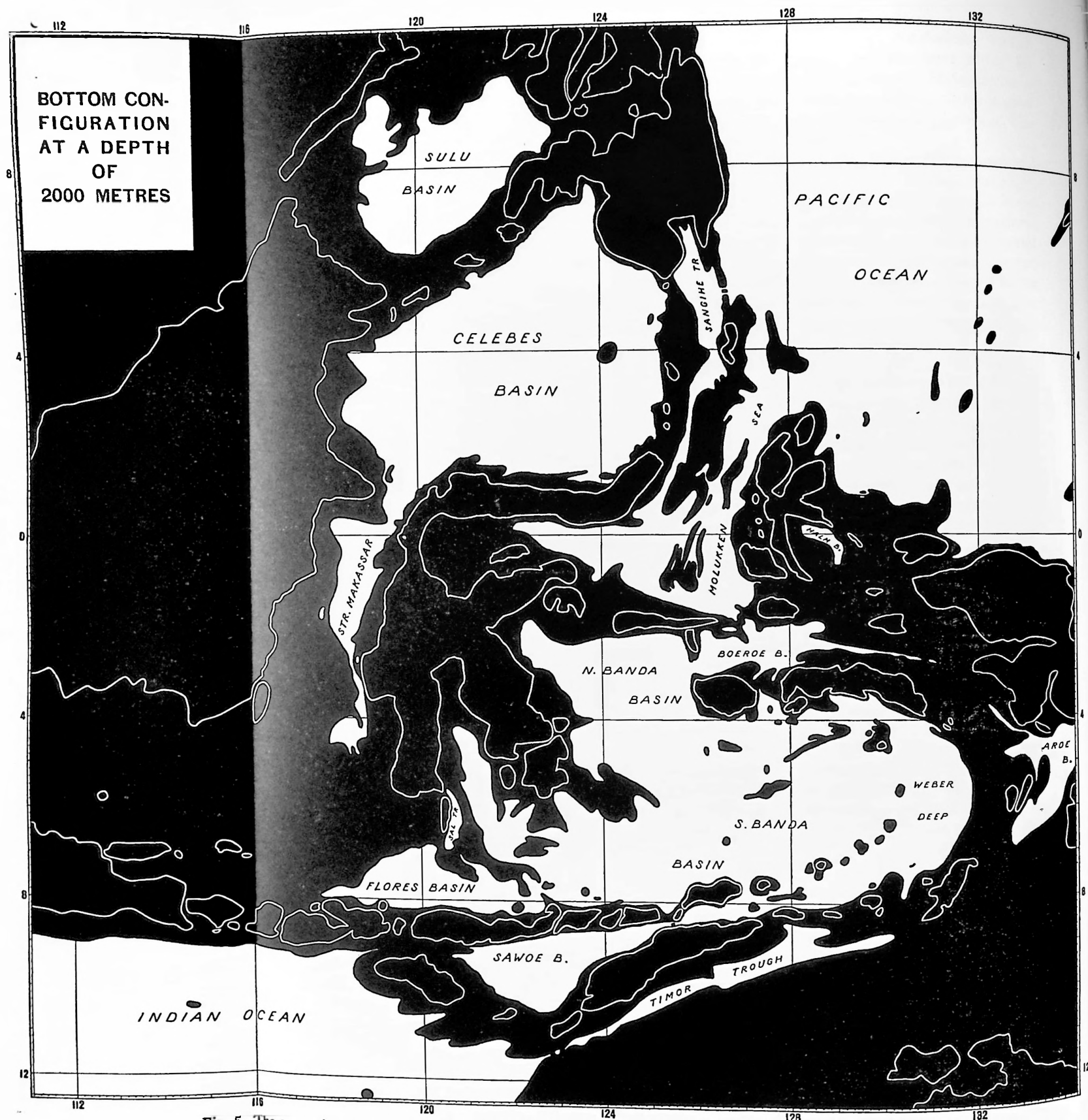


Fig. 5. The connection of the islands mutually and with the Asiatic and Australian continent at a depth of 2000 m.

anchor-station was on our programme, so that on Aug. 8th we steamed back to st. 39a, where we anchored in 2250 m depth. For this two light anchors were used attached to a conical steel rope, 3000 m of which was payed out, occupying $3\frac{1}{2}$ hours; the total length of this rope was 7500 m, plate XXVIII. Particulars of the anchor machine and the method of anchoring are given by Lieut. Perks in Ch. II.

This anchoring had a double purpose. The current at the surface can be determined when under way from the difference in the place of the ship found by dead-reckoning and by observing celestial bodies or bearings of conspicuous points ashore, but for the determination of current at greater depths it is necessary that the ship should form a fixed point in relation to which measurements can be made. We must not expect too much from this „fixed” point, in practise the ship sways round the anchor with changing current and wind. It is impossible at such great depths so to anchor a ship before and aft that it will remain absolutely in one position. Mooring the ship with two anchors ahead in great depths also presents difficulties so that the possibility was considered of using a buoy near the ship and anchoring it to a wire of about the same length as the depth of the place. In this way the movement of the ship with relation to a comparatively fixed point could be determined and be allowed for in the calculation of the current. But the plan was abandoned on account of technical difficulties.

Only in cases where the drift of the ship from hour to hour, including the night, can be accurately determined is anchoring superfluous and the current in the deep layers can be calculated from the measurements after applying a correction for the ship's drift.

Another problem called for our attention as well as the measuring of currents. We had to make out in how far the properties of the sea water which we determined below the surface, such as temperature, salinity, etc. remained constant for any length of time. Only if this should prove to be the case could the observations, in a cross-section for instance, be treated as if they had been taken simultaneously and the distribution of the above properties in a vertical direction represent a condition of some permanence. As observations in other regions had shown that periodical changes in the properties of the upper water layers occurred at short intervals, it was desirable to investigate this problem also. For this purpose at most ordinary stations the first series was repeated at the close of the station.

The anchor-stations offered however a better opportunity for examining these changes by repeating the serial observations at some niveaux of the upper layers at fixed intervals. We selected for these observations the surface and depths of 50, 100, 150, 250 and 500 m. At these niveaux water samples were hauled up every 2 hours for 24 hours, while the temperature was determined at the same time. The salinity and oxygen contents of the samples were determined in the laboratory. After calculating the deviations from the mean value in the 13 results, it appeared that the oscillations in the different niveaux agreed very well as regards the phase, while the period was prevelantly semi-diurnal.

The observations were made very difficult by the current. Although a weight of 50 kg was attached to the wire beneath the samplers, there was always a greater or less incline of the wire according to the rate of the current. Thus the samplers were seldom at their exact niveau, and at different depth in the successive series, this not being marked by the dial of the measuring wheel. At two places, therefore at 150 and 500 m a protected and an unprotected thermometer were attached to the water samplers so that the depth of these niveaux could be deduced from the two readings and could be obtained for the others by interpolating. All this, however, entailed that the temperature, salinity and oxygen content could not be determined for the niveaux 50, 100, 150, 250 and 500 m. The values for these depths had to be deduced from the curves which were drawn from the material available.

During the whole of the time the ship lay at the anchor-station the current at the surface was measured every hour by the officer on duty. He also noted down the weather conditions, the state of the sea, the course of the compass, the direction in which the anchor rope stood out and its inclination, the readings of the dynamometer by which the tension of the steel anchor rope was given and further any particulars which might show the position of the ship every hour in regard to the place of the anchor and the moment when it had changed its position in this respect. Any irregularities that might appear afterwards in the results for the current may be explained by consulting these data. The results of a number of astronomical observations showed that the anchor had „held” from Aug. 8th to 11th.

At the end of the serial observations, the direction and the velocity of the current were determined for a period of 24 hours in 50, 125 and 400 m while some observations were made at a depth of 1900 m. The wind and the surface current were almost opposite in direction, which kept the ship in a favourable position for making current observations on port side.

The observations with the Ekman-Merz current-meter in 50 and 125 m went smoothly; the drawback of the instrument is that it has to be hauled in after each observation. For this reason in the niveaux of 400 and 1900 m Ekman's repeating current-meter was used simultaneously, with which a number of observations can be taken in succession, plate VI. This method, however, has another disadvantage. As the instrument remains suspended in the water for hours at a time, there is a great chance of jelly-fish and other obstacles attaching themselves to the line. All unsuspecting we sent down the line every hour three messengers at intervals of say 3 minutes in the hope of getting two current averages in 3 minutes. But all the messengers encountered the obstacles on the rope and were lost, so that when the instrument was hauled in after 47 messengers have been used, it appeared that no observations whatever had been made. This difficulty confronted us at st. 39a, we tried to listen for the impact of the messenger on the current-meter with an improvised microphone, but this was only effective down to 400 m depth.

The strongest current was found at 50 and 125 m depth, as a mean value we observed about 1.6 and 1.2 sea miles per hour in a S.S.E.-ly direction, while the mean surface current was S.E. 0.6 sea miles. The current was still less at 400 m and near the bottom only a very feeble movement could be observed. For the results of the observations at the anchor-stations we refer to Vol. II, Part 3.

On Aug. 11th at 7.30 a.m. we began to weigh anchor; at 1 p.m. it had been accomplished. After a final wire sounding we steamed away at 2 p. m. to the north, where south-east of Cape Mangkalihat we found the depth to be less than was marked on Tydeman's chart. The neighbourhood was sounded by echo-soundings (detail chart 1) which showed that the 1000 m line extended from the Cape to about the middle of the Strait.

On August 12th the „Snellius” got into touch by wireless with the Danish research ship „Dana” which was on her way from Menado to Soerabaia, principally occupied with biological research under the direction of the late Prof. Joh. Schmidt. Shortly after we saw the masts of the ship appear above the horizon. To my regret the arrangements of the Danish ship were not compatible with a plan I had formed for meeting them near the N.W. point of Celebes.

On Aug. 14th the ship headed north and steamed between Moearas reef and the island of Maratoea in the western part of the Celebes sea, and after inspecting the neighbourhood Boschma and Kuenen with their „mantri's” were put ashore on the island in the company of Lieut. Perks and seven men of the crew, who the Commander had put at their disposal, with a motor boat and two flats, to investigate the atolls (Ch. IV). The same day we proceeded to Tarakan for a further supply of fuel, where we anchored in the roads of Lingkas on the 15th. As on the previous Sunday we had worked the whole day the next day was a holiday, of which use was made for a visit to the island and the oil fields in particular. The fields are reached by a walk of about $\frac{3}{4}$ hour along a glaring road or by boat on the river, which debouches into the sea to the east of Lingkas. Where the virgin forest has given place to drilling-towers the ground is saturated with oil. The river, covered with a thin layer of oil presents a dreary picture, the white trunks of the defunct forest giants, stripped of branches and leaves rise high aboven the low brushwood and the silence is unbroken by any call of birds. On the oil fields they are hard at work, extending their operations and setting up accomodation for the personnel of the Tarakan Company. Under the guidance of my former naval colleague, the superintendent M. van Nymegen Schonegevel, much care is being expended upon the construction of good roads and the improvement of the hygienic conditions.

The following day, Aug. 17th our oil tanks were replenished and we steamed to Maratoea; both on the journey there and back the area between this island and Tarakan was sounded. On Aug. 18th those who had been left behind at Maratoea came on board; Boschma and Kuenen somewhat richer than when they took up their primitive abode there.

After leaving Maratoea, stations 46—51 were worked off, which again filled the laboratory with an alarming number of water samples. We were here chiefly concerned with very deep stations, including st. 48 with a depth of more than 5500 m; moreover the stations on the steep coast of Celebes

had to follow one another rapidly if we wished to have a succession of a station in great depth, one on the island slope and one near the coast in shallower water.

The north coast of Celebes offered a quiet and beautiful spot for rest in the immediate neighbourhood of the last station, 51, east of Palehleh, in front of the village Tang where we stayed for Aug. 21st and 22nd. These two days gave the chlorine analysts an opportunity to work through the accumulation of water samples while Boschma and Kuenen continued their research on shore and on the coastal reefs, as they had done at Mamoedjoe. Tang is a well kept and picturesque native village. It was a great relief to be able to go for a good walk once again, along a good road through coco-nut plantations in the direction of Palehleh. On such a walk the thirsty pedestrian learns to appreciate the milk of young coco-nuts, for which the friendly natives ask no recompense.

The weather had been in general favourable. Occasionally we had met thunderstorms in the Celebes sea with strong westerly breezes. On Aug. 19th a uniform grey sky promised no good, and shortly before station 47 was reached, a heavy gale, force 10, of short duration broke from the north-west. As it was impossible to manoeuvre the ship under these circumstances the station was postponed and the ship laid to for a few hours. At this station we had the same difficulty with the serial winch that we had experienced with the Lucas sounding machine on the outward voyage. After 3800 m had been payed out the running wire wedged in the layers still on the drum, so that the paying out to 5000 m had to be done with the utmost care and precaution. In this case the slackness of the wire was probably caused by having been wound round the drum at a temperature much lower than in the Indies. Before hauling in the wire rope the layers still on the drum were covered with triplex wood.

On Aug. 22nd we left the roads of Tang and steamed to the middle of the Celebes sea. At the request of the Commander I had arranged the observations so that we could be at Menado on Aug. 26th. At st. 54 some delay was caused when, lowering the bottom-sampler, the stiff piano wire, presumably being payed out too rapidly, sprung back and lay loosely on the drum. Apart from this all the stations went so smoothly that by Aug. 25th we could anchor in the roads of Menado, thus completing one track. We now had a few quiet days in prospect, during which the nights were untroubled by the sound of serial or sounding machines, and no interruption in the normal paying out of the wire raised anxious thoughts in my mind as to the fate of the instruments suspended along the line. But there was as yet no rest for the chlorine analysts, it was not till Aug. 29th that the last salinity titrations were completed.

Menado is the capital of the Residency of that name, which includes the N.E. of Celebes with the islands Talaud and Sangihe. The landscape gives the impression of great prosperity, the majority of the population has been converted to Christianity. During our stay at Menado the resident, H. J. Schmidt, and the Minahassa Council very kindly offered a motor drive to some of the members of the expedition round the Lake of Tondano, so that we could enjoy the beautiful scenery with its neat and picturesquely situated villages.

To see something more of the neighbourhood and to escape for a moment from the heat, my wife and I spent a night at the pasangrahan ¹⁾ at Tomahon, which lies inland at a height of about 800 m. It was a serene tropical night and the clear depths of the sky displayed the stars with a surpassing beauty, where the Milky Way spread across the firmament like a huge glittering cloud.

On Aug. 31st the „Snellius” was dressed in her festive robe of pennants in honour of the birthday of Her Majesty the Queen, plate X. That afternoon, at the house of the Resident we were present at the „open reception”. All civil and military authorities came to present their congratulations, which were forwarded to Her Majesty through the Governor General. Sunday Sept. 1st we remained at Menado and departed from the roads next morning, plate XXIII.

b. SECOND TRACK, MENADO-TERNATE. SEPTEMBER 2nd-23rd, STATIONS 56-79.

Taking into account the probable weather conditions, it was my intention to make observations in the Sulu Sea during September and to lay a cross-section through the Celebes sea, from Menado to Basilan strait on the way there. Remembering our experiences in the first track it seemed advisable to reduce the number of stations in the Sulu sea.

On September 2nd anchor was weighed, with the intention of proceeding to station 56 in the middle of the Celebes sea after a series of echo-soundings on the steep slope of Menado Toea, a

¹⁾ A pasangrahan is a usually very simple building for the use of officials when travelling.

small volcanic island lying about 20 km N.W. of Menado. On September 4th the sky was covered by Cs-clouds, the weather warm and close and a considerable swell came from the south. According to a wireless message a typhoon was passing at $\pm 17^\circ$ N. of us, which probably accounted for the unfavourable state of the weather. An attempt was made that day at st. 57 to take three observations at distances of 30, 60 and 90 m above the sea bottom, to test whether the chemical properties of the sea water showed sudden changes at these depths. For this purpose to the lead line (30 m hempen rope) 60 metres of stranded steel wire (diameter 4 mm) was attached and above that again the piano wire. On the steel wire 3 light Sigsbee water bottles were hung and a thermometer frame with a reversing thermometer; at the end of the hempen rope was the Ekman bottom-sampler. After 100 m had been hauled in the piano wire broke at a joint and 4500 m of wire with the instruments was lost. It is possible that the joint was no longer sound and in future every time that one passed over the guiding wheel it was well inspected.

The further north we went the worse the state of the sea became, it was tiresomely choppy, a condition by no means favourable to mental exertion. Not until we reached Basilan strait in which sts. 59—61 lie, did quiet return. It was already dark when on Sept. 5th we passed the narrowest part of the strait, at unusual speed being helped by a strong current. The lights on shore and those on the steamships lying in the roads of Zamboanga gave a lively and cheerful appearance to the scene.

The observations of station 64 may be compared with those carried out 55 years previously at $8^\circ 0'$ N. and $121^\circ 42'$ E. by the „Challenger” (station 211). To a depth of 400 fathoms (732 m) the temperatures are in good correspondence with those of the „Snellius”. Below this level, however, owing to the use of minimum thermometers, a constant temperature of $10^\circ.3$ C. has been measured instead of a lowest temperature of $10^\circ.08$ C. at 1200 m, increasing downwards to $10^\circ.44$ at 4000 m.

With st. 65 we had reached the central part of the Sulu sea. Here wind and sea were satisfactory, the sky was still uniformly grey and the air pressure below normal, but we experienced no more than a few squalls from the west. We were able to carry out our work regularly.

As the Sulu sea occupies a peculiar position amongst the inland seas of the Archipelago we must give a moments' special attention to the causes of this. In general the properties of the sea water in the basin below the depth of the deepest entrance, will be determined by the properties of the water which flows in across the deepest sill. The water beneath the sill inside the basin is therefore in general fairly homogeneous.

Now the deepest entrance to the Sulu sea lies to the west of the island of Mindoro, where water from the China sea cannot enter at a greater depth than about 400 m. Taking only the temperature of the sea water into consideration it follows that the water temperature of the abyssal layers in the Sulu sea must be much higher than in the Celebes sea, where the depth of the entrance lies 1000 m lower.

The water flowing in over the sill gradually reaches more profound depths in the basin and is therefore under higher pressure. In consequence of this pressure the temperature in depths below a certain niveau will begin to rise. The position of this niveau as regards the maximum sill depth is not uniform but in most cases it lies below the sill and in some even very far below.

The modern reversing thermometer enables the temperature to be read in five thousandths of a degree Celsius and so to ascertain very minute differences of temperature. The accuracy of the observations is still further increased by using two thermometers beside each other at the same niveau. In a series of 138 observations in the first track Hamaker found a mean difference of 0.009° C. in the readings of the two.

To illustrate the difference in conditions of life and the peculiar increase of temperature below a certain depth we give some temperature figures together with the greatest depth (sill depth) at which water can enter to renew the bottom water in each basin.

Celebes sea		Sulu sea	
Greatest depth	6220 m	Greatest depth.	5580 m
Sill depth	1400 m	Sill depth approx.	400 m
Temperature		Temperature	
1750 m	$3^\circ.69$	500 m	$11^\circ.00$
2475 m	$3^\circ.57^s$ minimum	1225 m	$10^\circ.07^s$ minimum
5000 m	$3^\circ.83$	4400 m	$10^\circ.51$

The temperature which in both inland seas is at the surface 28°—29° continually decreases until in the Celebes sea at about 2500 m depth the lowest figure is reached. From this depth the compression of the water causes the temperature to rise again down to the bottom. In the Sulu sea, the entrance to which lies so much higher, the temperature of the inflowing water is consequently also higher; the minimum is found at about 1200 m and the temperature in this basin down to the greatest depth remains about 7° C. higher than in the Celebes sea.

Besides the high temperature of the abyssal layers the bottom water here, in contrast to the Celebes sea, has an oxygen content much smaller than that found in the lowest water sampler of the serial observations. To investigate this further the experiment of station 57 was repeated at station 66, but without thermometer frame and instead of the heavy Ekman-sampler, plate IV, the Sigsbee-sampler was used, from which the weight of 25 kg was detached when the sampler struck the bottom. The greatest fall in oxygen content at st. 66 was observed at between 30 m and 60 m above the sea floor. Further research will be necessary to ascertain what connection there may be between the richness in lime of the sea floor as revealed by the bottom samples and the poorness of oxygen content in the bottom water. To provide sufficient data concerning the sea floor a second wire sounding was carried out at the same station with an Ekman-sampler. As this was followed by a haul with the large plankton net at a depth of 3000 m, the observations at this station lasted for 11 hours.

Work in the Sulu sea was terminated with a cross-section in Sibutu strait, stations 70—72, detail chart 2. A busy week lay behind us, during which observations had continuously been made at 17 stations and at more than 300 niveaux, while about 400 water samples had been collected. The stations followed each other in rapid succession so that everyone, and especially the chlorine analysts, had their hands full.

A short rest settled upon the ship, when in the afternoon of Sept. 9th we anchored on the east side of the Sibutu strait, see detail chart 2. The Commander had found a sheltered spot near the village of Bongao south-east of the Sanga-sanga island.

The following morning we steamed to the narrow strait west of the island of Sibutu, where Kuenen and Boschma were deposited with the necessary boats and men under command of Lieut. Van Straelen (Ch. IV). Hamaker accompanied them for pleasure and also to assist in taking photographs under water on the coral reef. The ship departed the same day to take in fuel at Tarakan, where we anchored in the forenoon of Sept. 11th in the roads of Lingkas.

While here some of the company gratefully accepted the invitation of the Superintendent to visit the boring station. After that my wife and I spent some pleasant hours under the hospitable roof of Mr. and Mrs. van Nymegen Schonegevel.

On the return journey to the Sibutu strait echo-soundings were carried out, amongst others a spot to the east of Tarakan was sounded, where a shallow of 12 m was marked on the chart. This shallow was not found, however. Sept. 14th was devoted to current observations in Subutu strait. Considering the hard sea floor and the strong surface current of from 2 to 4 sea miles per hour I did not expect much success in anchoring. However, to get a better idea by direct measurements of the exchange of water between the Sulu sea and the Celebes sea, even in the deepest layers, we carried out our current observations with a drifting ship *in dead calm* weather. By minutely determining the displacement of the ship by bearings of conspicuous points on shore the surface current was found. The measurements in deeper layers were corrected for this displacement, detail chart 2.

Sunday Sept. 15th we returned to the place where we had set off the landing-party. That afternoon all returned on board in good health, but soaking wet from a rain-squall, that had just broken. Before dark the roads of Bongao were reached, where the ship remained the following day, to enjoy the holiday ordained for H.M. Navy in celebration of Royal Colours being presented to the corps of Marines.

The programme for Sept. 17th contained some subsidiary current observations and soundings. After these had been executed, stations 73—76 terminated the 2nd profile across the Celebes sea to the north of Makassar strait where station 76 fell on the same spot as st. 48. In this way the observations at this point were repeated after the lapse of just a month. At the same time water samples were raised from the niveaux 30, 60 and 90 m above the sea floor, depth about 5750 m, to test the differences in the oxygen content at a short distance from the bottom.

As the water sample from the lowest sampler, marked M. 34, showed a strong increase of oxygen

content, some doubt was thrown upon the proper functioning of the instrument. To check this, the following day, three samples were raised from about the same depth (75 m) with this sampler and two others. The chlorine content of the sample raised in M. 34 proved to differ considerably from that in the two others. On being carefully examined it proved that the instrument did not close properly.

At the same time Hamaker tested the working of the Sigsbee water bottles, constructed by messrs. Seemann (of Hamburg) and messrs. Marx & Berndt (of Berlin), by comparing the salinity of the water samples procured by these instruments with those coming from the Nansen water bottles. The experiment was repeated twice in 75 m; the results proved satisfactory. The Nansen water samplers delivered by Marx & Berndt in Berlin and Bergen Nautic at Bergen showed the same salinity at the same depth.

Sept. 21st and the following day were devoted to stations 77, 78 and 79 (detail chart 3) after soundings in the southern portion of the Celebes sea and the steep submarine slope of the island

of Menado Toea. These three stations gave the connection of the Celebes sea with the Molukken sea along a longitudinal section, which runs across the Biaro strait.

During the Siboga-Expedition (1899/1900) a polished boulder was hauled up with the dredge from a depth of 1200 m at „Siboga” station 122 in the western part of this passage. Tydeman¹⁾ surmises in this connection the occurrence of a strong sill current, a submarine river, renewing the abyssal water in the Celebes sea. The following is stated by him:

„Voor een drempelstroom als die tusschen Molukken Passage en Banda-zee zal wellicht de stroomsnelheid zoo belangrijk zijn, dat aan zulk een constant vloei-

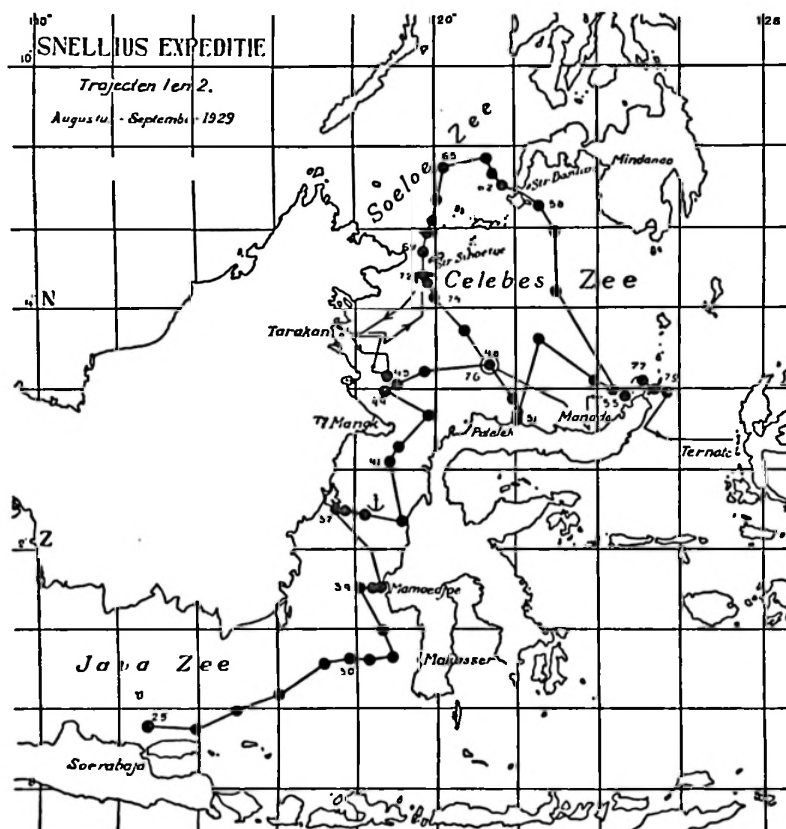


Fig. 6. Stations on the 1st and 2nd track.

enden stroom met recht den naam van diepzee-rivier of diepzeestroomversnelling zou kunnen worden gegeven. De erodeerende werking van zulk een stroom zou dan echter ook van geologische betekenis zijn, daar zij in sommige opzichten met die van een rivier aan het aardoppervlak gelijk zou staan. Zoo zou b.v. de vorming van rolstenen niet kunnen uitblijven. Het voorkomen van een grooten, regelmatig gevormden, gladden rolsteen in den diepzeekor van de Siboga op Station 122 aan de westkant der passage tusschen Celebes' noordoosthoek en het eiland Biaro uit eene diepte van 1264 m (afnemend tot 1165 m), steengrond, welke vangst met eenige verwondering werd geconstateerd, zou daarmede eene gereede verklaring vinden".

Sunday Sept. 22nd, a succession of soundings were made over the Molukken sea, in connection with the configuration of the sea floor in this area. The following day towards sunset we anchored in the roads of Ternate.

¹⁾ De Zeeën van Ned. Oost-Indië, p. 121. E. J. Brill, Leiden, 1923.

During the first and second track the following physical-chemical determinations were carried out.

	t	S	O ₂	A	pH	Wire soundings
Serial observations.	1056	1073	834	78	868	61
Surface observations	276	256				

Moreover the surface temperature was constantly registered by a resistance thermometer.

The wire soundings did not all yield a bottom sample, owing to the defective functioning of the sampler, the escape of the sample or the breaking of the wire. According to the measurements made by Kuenen on board, the mean length of 47 samples collected was about 45 cm, the greatest length being 87 cm. The length is intimately connected with the nature of the sea floor.

These samples were hermetically sealed up in glass tubes, plate XVIII, and with the material Kuenen had collected on the islands and reefs, were sent to Holland as soon as a fresh supply of material had been collected. Kuenen was only able to examine them very superficially on board, no weighing, for instance, was possible. The object of the provisional determination was only to gain a general idea of the sedimentation. Positive results obtained from the final examination will be given in Vol. V, Part 3.

A great number of echo-soundings threw much light upon the configuration of the sea floor. Important differences from the existing chart were found only in the northern entrance to Makassar strait.

Plankton was collected from the surface at nearly every station and from the deeper layers by means of closing net or tow-net (straminpose) at 26 places. Dredging took place twice. More particulars may be found in Vol. VI. The collection of surface plankton by a net suspended from the side of the ship could only be done when there was a surface current, so that the ship was obliged to pass through the water at a very slow speed to keep in place for purposes of oceanographic and geological observations. The plankton material was provisionally sorted out by Boschma and with the corals and coast fauna sent at regular intervals to Holland.

The results from the Meteor-expedition as well as the research done by the „Snellius” in the Red sea, had shown the important bearing of oxygen analysis upon the question of water circulation. Generally speaking it appeared that a layer with a minimum oxygen contents is rather stationary. According to Wattenberg¹⁾ the maximum and minimum values for the contents of oxygen may result from a varying equilibrium between the consumption of the constituent and its regeneration by chemical processes in the sea. In this case it can not be taken for granted, therefore, that the movement of the water in a layer with a low contents of oxygen is slow.

The small settlement of Ternate, plate XX, lies along the coast at the foot of the great volcanic mountain rising up out of the sea; the roads offer a quiet place of rest. After the commander and I had paid an official visit to the Resident, Mr. Hovenkamp, the latter was so kind as to invite the staff and officers to witness an ancient war dance performed for us by natives arrayed in full war costume. In many other ways entertainment was offered us showing that every effort was being made to render our stay at Ternate as pleasant and refreshing as possible.

Ternate provided many opportunities for walking, both along the shore and up the slopes to Ajar Tikki-Tikki, where the abundant nut-meg trees protected us from the heat of the sun. We made an interesting expedition to the „Burned Corner” where an ancient lava stream flows into the sea, the heavy masses of rock bearing witness to the violence of an earlier volcanic eruption. If a refreshing (!) bathe at 28° C. is desired after a hot walk, this can be enjoyed on the coast where a spot in the sea has been fenced off by wire netting, to prevent any danger of being disturbed by the attentions of sharks. It was a pity that during our stay at Ternate the heat was so extremely oppressive, the afternoon rain giving very little relief.

¹⁾ Conseil Permanent International pour l'exploration de la mer. Rapp. et Proc-Verb. Vol. CV 1ère partie. Juillet 1937, p. 31.

c. THIRD TRACK, TERNATE-KOEPANG. SEPT. 30th-OCT. 31st, STATIONS 80-129.

During our stay at Ternate the remaining water samples were titrated in the laboratory, and were completed by Sept. 27th. Sept. 28th was devoted to echo-soundings on the sub-marine slopes of the island of Tidore. After one more day of rest we left the roads early on Monday 30th.

As favourable weather conditions might be expected in the east and south-east of the area, for the months of October and November an investigation of the troughs and basins here stood on our programme, together with the adjacent part of the Indian Ocean. We therefore laid our course through the Molukken sea towards the south where bottom and serial observations were made to a depth of 4600 m in the Batjan trough, at station 80. For the investigation of the water exchange between the Molukken sea and the Halmahera sea we sailed round the north of Obi island to the east taking observations at the relatively shallow stations 81 and 82. A cross-section with stations 83-86 gave us information concerning the properties of the sea water in the transition area between the Halmahera sea and the Ceram sea. The high chlorine percentage found at about 150 m depth here was a surprise; it proved later that there was a water transport from the Pacific Ocean at this niveau, through the Halmahera sea to the south-east part of our field of research. Figures 14 and 15, p.p. 136 and 138.

Kuenen had expressed the opinion, that, as we were now in the neighbourhood of Misool, a visit to some of the islands of the group would be of value, as a great variety of fossils were to be found there. Boschma would also have the opportunity for examining the coral reefs near by. They would so be able to make good use of their time while the ship took in fuel at Ceram, for which there was no opportunity at Ternate. Consequently on Oct. 3rd they were both put off at Kafal, a small island south of Misool, in one of the motor boats with crew under orders of Lieut. Veldman. The ship departed the same day for Boela, the petrol station on the north coast of Ceram. While we were moored to a pier running far out into the sea carrying the pipe line, the business was quickly and easily accomplished and we returned next day to Kafal, where we spent a Sunday and where the geologist and biologist returned on board. The reputation of these islands as the prime finding place for fossils tempted several of those on board to pay them a visit and armed with a hammer, or otherwise, to shatter large blocks of stone in the hope of finding traces or actual remains of prehistoric times. In most cases their hopes were not disappointed.

When all were embarked once more, we departed on Oct. 6th from our berth at Kafal and steamed to a point on the N.E. coast of Ceram east of the petrol station Boela. Between Kafal and Boela a great number of echo-soundings were collected, throwing much light upon the bottom configuration of the Ceram sea. The information thus gained was very useful to us later on in arranging situations for the stations at our next visit to the Ceram sea. The number of soundings, collected on the station-tracks only, was not sufficient to give a complete knowledge of the very uneven bottom configuration of the Ceram sea.

From the point to the east of Boela observations were made on a cross-section of 5 stations (87-91) as far as the contour of depth of 200 metres bordering the New Guinea shelf; on a similar section between the Watoebela islands and Cape Van den Bosch we made observations at 5 stations (92-96). The soundings on these two profiles, which we completed on Oct. 9th indicated a narrow depression with a depth of about 2000 m which extended along the north side of the Ceram sea parallel to the edge of the New Guinea shelf. Near Cape Van den Bosch this depression did not exceed 5 sea miles in width. Later we discovered that in this channel there was a ridge between the two cross-sections at 1600 m depth.

From Cape Van den Bosch, the next areas to be investigated were the Ceram trough, the Kai-Aroe trough and the long narrow depression which extends from there to the Indian Ocean, parallel to the Australian shelf. The echo-soundings which were carried out on the way to Dobo (Aroe islands) showed at once that there is no submarine dividing ridge between the Ceram trough and Kai-Aroe trough, and later soundings confirmed the surmise that the area consists of *only one basin* which may be called the Aroe basin. The maximum depth was over 3600 metres. At station 97, which, according to previous depth charts, was situated in the deepest part of the Ceram trough, a depth of only 2400 m could be ascertained.

The visit to Dobo was made, according to a pre-arranged plan by Kuenen and Boschma, to

investigate the peculiar „soengai's”¹⁾ on the Aroe islands. Consultation with the government official there lead to the provision of a pilot for the navigation of the creeks and a „mantri” (native assistant) to facilitate co-operation with the native population. On Oct. 11th we anchored before the western mouth of the Soengai Workai where the landing-party were put on shore and the geologist and biologist were left behind with a motor boat under command of Lieut. Perks.

The weather conditions continued favourable; in the northern part of the Ceram sea a slight swell was experienced, but this gradually subsided as we travelled more to the east and south. Clouding, however, increased so that there was little opportunity for fixing the position of the ship by astronomical observations. On Oct. 12th we steamed to station 98, the starting point for a third cross-section between the Aroe and Kai islands (stations 98—102). After making observations on Oct. 13th in 600 m on the rise of the sea floor to the north-east of the island Noehoetjoet, one of the Kai Group (st. 103) and in the deepest part of the basin at st. 104, we steamed back to the mouth of Soengai Workai, where we anchored on Oct. 14th. Here we had a day of rest, after the oxygen contents had been determined in the remaining water samples.

After the landing-party had returned next morning in their motor boat and the native pilot had been taken back to Dobo, Oct. 16th was devoted to soundings in the Aroe basin and on the shallower ridge between the Kai and the Tanimbar groups. After the bottom had been found to rise rapidly to 130 m during the night, we returned to a depth of 1000 m and followed this depth contour towards the south.

On Oct. 17th the fourth cross-section followed, with the two stations 105 and 106 on either side of the axis of the depression, where 1690 m was registered as the profoundest depth. A fifth cross-section, at right angles to the coast of the island Jamdena of the Tanimbar Group was formed by the stations 107—110. In the deepest part of the narrow elongated depression a maximum depth of 1600 m was found. Here the sill lies, which forms the barrier between the Aroe basin and the Timor trough.

After stations 111 and 112 had been worked off we proceeded between the Tanimbar and Babar Groups to the island of Wotap and anchored there on Sunday, Oct. 20th, in a small bay, detail chart 4. The coral reefs exposed at low water lying in the immediate neighbourhood of the ship offered a splendid territory for Kuenen and Boschma, plate XXVII. Kuenen, moreover, was provided with a motor boat so as to extend his research on shore to a greater distance from the ship. Their work being done, both scientists were able to return on board, so that it was not necessary for them to have recourse to primitive and very likely unhealthy accommodation for the night. On board the water samples were tested in the laboratory for which there had not been sufficient opportunity while under way. Thus the fixed programme could be followed, the instruments were all cleaned and put in order and calculations and drawings brought up to date.

On Oct. 23rd anchor was weighed. As the geologist was anxious to have as many depth data as possible for ascertaining the submarine connection between the Tanimbar and the Babar islands, a great number of soundings were made between the two islands. The oceanographer also got valuable information concerning the depth of the sill which divides the eastern part of the Banda sea from the Timor trough; this proved to be about 500 m. The echo-soundings which were made on Oct. 24th between the islands of Babar and Ternate with the same object, pointed to a second connection there at a depth of 1200 m on the sill. After this area had been charted, ordinary oceanographic observations were made at stations 113 and 114 in the above mentioned deepest channel. The first of these stations formed with 115, 116 and 117 the sixth profile where in the deepest part of the Timor trough a depth of 2420 m was found.

On Oct. 26th we steamed westward to the east coast of Timor, where, in the deepest part of the Timor trough a depth of fully 3000 m was registered at station 118. From the coast of Timor to the Sahoel shelf, the seventh and most important profile was concluded with the stations 119—123. The greatest depth found in this profile was 2650 m. Apparently the depth decreases in the axis of the trough in the direction of the Indian Ocean.

On Oct. 29th and 30th oceanographic observations were made on the last profile (st. 126—129). The geologist was anxious to raise bottom samples from the edge of the Sahoel shelf with the large Ekman-sampler of 4 m length, plate VI. It was hoped that here pleistocene littoral sediment would

¹⁾ Narrow creeks which cut the island from coast to coast.

be found below the later deposits. Some preliminary attempts with the ordinary Ekman tube and the Monaco-catcher had shown that the bottom on the shelf itself was too hard to be amenable for the purpose. Amidst general interest the large instrument weighing 140 kg was therefore payed out from the serial winch at station 128 and a bottom sample of 102 cm was raised from a depth of 1500 m. This sample consisted of globigerina ooze and was unstratified. When winding in the winch the dynamometer registered 500 kg as maximum strain. The steel wire rope of 4 mm diameter which had seen almost a year's service, had been so well looked after that there were hardly any weak points in it.

After a sounding track up to Roti strait we anchored on Oct. 31st in the roads of Koepang. It was high time that the track should be finished as the effects of too little fresh food had been felt for the last week and the observations at about 50 stations had put considerable strain upon everyone. Thanks to the conscientious care of those who were responsible and to the particularly favourable weather conditions the observations all ran smoothly.

The chemical activities were confined in these three tracks to chlorine, oxygen, p_H and alkalinity determinations. In consultation with Boschma and Boelman it was decided to abandon for the present determinations of phosphates and nitrates. Determinations of these would only be fruitful if quantitative plankton fishing was carried out simultaneously, which was not the case. As the time available for testing for phosphate was not great in any case, we came to the conclusion that it would be preferable to extend the determination of alkalinity. If later plankton should be quantitatively determined, corresponding phosphate determinations could be made in the same place (See p. 121).

The collection of plankton was carried out in the manner already described; surface plankton was obtained at most stations, while now and then closing nets and tow-nets were used for the collection of macroplankton.

d. FOURTH TRACK. KOEPANG-MAKASSAR. NOVEMBER 7th—29th, STATIONS 130—148.

Koepang, the capital of the island of Timor, is a remarkable spot, which both as regards the inhabitants and their dwellings differs from what we had so far met with, plate XX. Seen from the roads, the tile-roofed houses on the coast remind one of an old Dutch townstead, and invite one to make a nearer acquaintance with it. But going ashore is not so simple, as the jetty near the custom-house can only be reached by the motor boat at high water. The best way of reaching the shore was in the motor boat, taking a flat in tow into which we transferred close to land and then exerted our skill to step ashore dry shod.

Through the friendly offices of the Assistant-Resident Mr. Karsen, my wife, Commander Pinke and myself were able to enjoy the mountain freshness and to spend a few days in the pasang-grahan at Soë, plate XXVII.

On Nov. 7th the „Snellius” left the roads of Koepang and the fourth track was commenced. This included researches in the neighbouring part of the Indian Ocean and the passages that give entrance from the Ocean to the Timor trough and the Sawoe sea. Boschma and Kuenen were left behind on Timor to carry out investigations there, as at the end of this track we should be stocking fuel at Makassar and then return to the Sawoe sea to carry on our research in the basin. The making of wire soundings and the collection of bottom samples was thus delegated to Hardon and Hamaker by which their participation in the research was considerably increased. They willingly undertook this work for our geologist, who was thus enabled to collect valuable material on Timor. With the consent of Commander Pinke the medical officer Broekhoff was good enough to take upon himself the collection of plankton during the absence of Boschma.

We steamed through the straits of Samaoe and Roti. On coming out of the latter, we perceived at once that the sea was not so quiet as a week ago, there was a swell from the south-west which became troublesome and which persisted until on Nov. 28th we turned our backs upon the ocean three weeks later in the Sape strait. The sea disturbance and swell were not allowed to interfere with the carrying out of our set programme but we had been rather spoiled by the calm sea during the last few weeks. The constant roll was very tiring in the long run.

The first piece of work was to investigate the sill between the Timor trough and the Ocean, in which by a few zigzag tackings the smallest depth was determined at about 1900 m, detail chart 5.

After this the series of stations was opened by 130 on the sill, which was succeeded by 131 in the Ocean (3000 m depth) on Nov. 9th. It was our intention next to make observations outside the entrance to the Sawoe sea to the east of Soemba (Sawoe strait) at 2000 m; on arriving at the place arranged for this, however, it proved that the existing chart was not correct, so that we only found 1300 m, st. 132.

Sunday Nov. 10th we steamed to the small island of Dana, lying to the west of Sawoe and began from there the sounding of the Sawoe strait. After we had obtained sufficient depth data to determine the right places for the stations, oceanographic observations were undertaken on a cross-section, sts. 133—136; detail chart 5.

As it was not desirable to interrupt the observations for a day of rest on Nov. 10th, we did not anchor till the evening of Nov. 13th at 10 a.m. before Seba, a small native village on the north side of the island of Sawoe, and had our day of rest there. A visit to the village and the Raja residing there gave us an opportunity for very welcome exercise, plate XXVII. To our great surprise we found that motor cars had found their way to this remote island. As on other islands, the beautifully coloured product of the loom (*Kains*) wrought here by the natives, tempted several of our party to make purchases on Seba. It is a pity that one can no longer be certain that what one buys has really been woven and dyed by hand in Sawoe, as the decorative native cloths are gradually being replaced by imported machine made articles, which are considerably cheaper, but of which the colours are much less permanent.

On Nov. 15th we steamed to the second entrance from the Indian Ocean to the Sawoe sea, Dao strait. This strait was sounded as given in detail chart 5 and, after the soundings had been entered on the rough chart, we found here also a depth of about 1200 m. After these depth-determinations we took observations along a cross-section between the small island of Dao and the island of Sawoe, sts. 137—140, and at a station to the south in the Ocean, to a depth of about 1500 m, st. 141.

To obtain data by direct measurements concerning the exchange of water between the Indian Ocean and the Sawoe sea, I had decided to take advantage of a suitable opportunity for making current measurements in one of the two straits at the east and the west of Sawoe. The numerous depth-determinations would enable a good anchorage to be chosen and we had learned something of the rate of the surface current and the nature of the sea floor. Anchor-station 135a was chosen on the sill of Sawoe strait. We anchored here on Sunday evening, Nov. 17th, at a depth of about 1150 m. Paying out the anchor with 1750 m of wire rope lasted for about 2 hours.

Before beginning the current observations, 26 hours were devoted to raising 14 series of water samples from niveaux 0, 50, 75, 100, 150, 200, 250, 400 and 700 m the temperature of which was determined. After determining the salinity of the 126 water samples we were able to study the periodic variations in temperature and salinity during the time of observation and to ascertain the eventual connection of these with tidal influences. Below the series a weight of 40 kg was attached to decrease the incline of the wire.

After this for fully 24 hours current observations were taken every two hours, the current-meter being paid out to a depth of 20, 50, 75, 100, 150, 200, 400, 600, 800 and 1000 m successively. Generally speaking the observations were satisfactorily accomplished, although occasionally there was some trouble from the yawing of the ship. This impaired the accuracy of the observations, so that they had to be repeated. Once the messengers stuck at the top of the repeating current-meter so that the instrument did not work. Another time the wind screen was not taken from the front of the screw before paying out the instrument. Current measurements at the surface were carried out for 89 hours, moreover the officer on duty made notes all the time on the weather conditions and sea disturbance and everything that might cause any irregularities in the results.

The astronomical observations showed that during the period of observation (about 4 days) the ship had not dragged at all, the weather conditions had certainly been in our favour. To obtain satisfactory results from an anchor-station, the first necessity is that the anchor should „hold”. But even then the tidal currents may cause a considerable displacement of the ship in regard to the locality of the anchor. There was reason to expect this in the Sawoe strait. The inflow current was, however, much stronger than the outflow, so that the influence of the former and the direction of the wind held the ship pretty well in position although some yawing was inevitable. The greatest speed that we measured was 1.5 sea miles per hour at a depth of 20 m. At a depth of 1000 m the motion was very slow, viz. a mean of only 0.2 sea miles per hour.

In the afternoon of Nov. 21st the anchor was weighed which took only $2\frac{1}{2}$ hours, after which oceanographic observations were made north of Sawoe strait at st. 142, depth 2000 m. The following day we anchored in the roads of Waingapoe on the north coast of the island of Soemba, the residence of the representative of the Netherlands government. Here we spent a quiet day. The Assistant-Resident, Mr. Young, was so kind as to invite us to go for a motor drive through the hilly interior. Owing to the dry east monsoon the grass on the slopes was all parched and food for the cattle extremely sparse. Only in the narrow valleys, where even at this time of year the ground is not completely dried up a few trees offered a little shadow. The water wells, from which the inhabitants were only allowed to draw water at certain hours, were rigorously guarded. Dreary indeed was the landscape, where only a few solitary ponies sought vainly for a green blade of grass.

After leaving Waingapoe, oceanographic research was carried out from the south-eastern point of the island of Soemba, st. 143, to the most southern station 146 in the Indian Ocean. Near st. 145 we passed through the narrow Soenda trough for the first time and found as greatest depth there 6390 m; steaming back to the north the same depth was found at about 90 sea miles to the west of this point.

In the vicinity of station 144 lies „Gazelle” station 95. About 54 years previously this ship carried out temperature observations on May 10th 1875 at $11^{\circ}18'$ S. and $120^{\circ}9'$ E. The temperatures are considerably lower to a depth of 2000 m; even approximately 2° C. at 1000 m. This may be due to seasonal and yearly variations.

The weather gradually began to assume the characteristics of the west monsoon, usually moderate westerly winds occasionally becoming strong; but so far without rain. A short but occasionally high swell from the south-west reduced the speed of the ship to $5\frac{1}{2}$ sea miles per hour. The observations at the deep stations, however, were accomplished smoothly, those at st. 146 lasted from 5.30 a.m. to midnight of Nov. 25th.

When the swell is high it is important in great depths to increase the weight of the Sigsbee lead to at least 35 kg, as otherwise the Lucas sounding machine does not automatically stop in time and wire is still payed out after the lead has reached the bottom.

After the last station in the Ocean and the one before the entrance to the Soemba strait had been worked off it was time to replenish our fuel and we steamed through the Sape strait to Makassar where we anchored on Nov. 29th. On the way there a great number of echo-soundings were taken in the Flores sea.

In and to the north of the Sape strait the south-westerly wind blowing from the Ocean backed to the south following the axis of the strait while rapidly decreasing in force. North of the Lesser Soenda Islands we again enjoyed calm weather and a smooth sea.

During the third and fourth track the following physical- chemical determinations were carried out:

	t	S	O ₂	A	pH	Wire soundings
Serial observations.	1370	1376	932	125	1026	71
Surface observations.	354	352				

Plankton was collected from the surface at almost all stations; vertical catches were carried out with the closing net and the large tow-net 14 times, horizontal catches with the large tow-net 5 times. Dredge and plankton-catcher were used twice. The number of bottom-samples collected during the third and fourth track amounted to 60.

In connection with what has been said on page 102 concerning the temperature in the Sulu and Celebes seas a few more data are given below concerning the basins and troughs visited later. By „sill depth” is meant the depth of the deepest entrance. Here too only the temperature is given; the other properties of the sea water in the abyssal layers are of course also connected with the depth of the deepest entrance.

	Greatest depth	Sill depth	Minimum temperature
Batjan basin	4810 m	2550 m	2°.06 C at 2970 m
Aroe basin	3680 "	1480 "	3°.90 " " 2240 "
Sawoe basin	3470 "	2100 "	3°.39 " " 2360 "
Timor trough	3310 "	1940 "	2°.67 " " 2254 "
Soenda trough (Indian Ocean)	7140 " ¹⁾		1°.18 " " 4230 "

This again shows that the lowest temperature is found below the depth of the deepest sill. The higher the sill lies the higher is the minimum temperature. An exception is formed by the Timor trough, where a temperature is found which is lower than in the Sawoe sea while the sill of the trough lies higher. The reason of this is that the abyssal layers of the Timor trough are directly renewed by water from the Indian Ocean, *while the renewal of the Sawoe basin takes place by water from the Pacific Ocean*, after its passing over many successive sills. That the renewal of the bottom water in the Sawoe basin does not take place directly from the Indian Ocean had already been surmised from former investigations ²⁾. This is due to the fact that the connections with the Ocean are much less deep than those with the Banda sea.

Though Tydeman ³⁾ is in error when assuming homothermal conditions in the abyssal layers of the inland seas and his temperature data are too high, he is right in basing on the scanty number of wire soundings, then available, the surmise that the abyssal layers in the Sawoe sea constitute an unbroken continuation of the deep-sea layers of the Banda basin.

As an anchoring place was visited now and then, or because a deal of time was devoted to echosoundings, the laboratory was able to keep up with the often large numbers of water samples, and we were able to carry out our fixed programme. Moreover the analysts were becoming more and more practised in their work. *The oxygen contents was always determined in duplicate*. Although mutual differences between two titrations are always slight, a double determination is very desirable considering the minute variation of the oxygen contents with depth especially in the abyssal layers. The chlorine determinations were carried out *at least* twice for each sample.

e. FIFTH TRACK, MAKASSAR-SOERABAIA. DECEMBER 5th—29th, STATIONS 149—170.

On December 5th we left the roads of Makassar and steamed back to Sape strait by another route, which enabled us to take a second series of depth-determinations in the Flores sea on a line parallel to the one taken on the way there. The day before, while weighing anchor, we had witnessed the moment at which St. Nicholas stepped ashore on the jetty at Makassar and was greeted by the inhabitants with lively enthusiasm; the following day we celebrated the time honoured festival on board. The officers and members of the staff had the happy idea of inviting my wife, the Commander and myself to dinner in the mess-room, where, through the absence of Kuenen and Boschma, there was room enough for us all to be united at one sociable table. The well arranged meal and the menus decorated with appropriate drawings all contributed to the genial atmosphere.

In the north and in the middle of the Sape strait oceanographic observations were carried out at sts. 149—150 and the investigation of the Sawoe sea was continued, sts. 150—155. At Koepang the biologist and geologist again came on board, after a fruitful stay of four weeks on the island of Timor (see Ch. IV). On Sunday Dec. 8th the Commander and the members of the staff told those on board something about the research and some of the results already obtained.

At a short distance from station 153 lies the „Gazelle” station 96. On May 12th 1875 temperature observations were carried out by this ship to a depth of about 3000 m at 9°57' S. and 121°52' E. In correspondence with the results of the comparison of „Snellius” station 144 and „Gazelle” station 95 (see page 110) here too the temperatures to a depth of 2000 m were lower in the year 1875,

¹⁾ In the eastern part.

²⁾ G. Schott. Die Niederländische Tiefsee-Expedition auf der „Siboga”. Annalen der Hydrographie und Maritimen Meteorologie, 1904, S. 108.

³⁾ De Zeeën van Ned. Oost-Indië, p. 119. E. J. Brill, Leiden 1923.

although not so conspicuously. The temperature of 2° 3 C., obtained by the „Gazelle” at a depth of 900 fathoms (1646 m) is probably 1° C. too low.

Before continuing the observations in the Sawoe sea we passed through the Roti strait to the sill between the Timor trough and the Indian Ocean. After the charting of the previous depth-determinations a further research proved needful to obtain more certainty as to the depth of this sill. Supplementary echo-soundings were made, while at station 156 further particulars were collected of the sea water near to a newly found second sill to the south-east of the small island of Roti. The weather conditions were favourable on the whole, with the exception of Dec. 8th when at station 152 we were caught in heavy rain showers with thunder and a great deal of lightning; the first definite signs of the near approach of the west monsoon so welcome to the inhabitants of this part of the Archipelago.

After our return to the Sawoe sea we proceeded to the west coast of Timor, st. 157, to carry out observations along a cross-section up to the island of Lomblen. When stations 158—160 had been accomplished, it was our intention to carry out observations to a depth of about 400 m at a final station near the south coast of the island. The depth proved, however, to be much greater than the map indicated. When, during the night, we had approached to within 2 sea miles of the coast we still found 1600 m. We abandoned the station and steamed eastwards to the Ombai strait. Here we found a lesser depth than given by the existing map and Sunday 15th we took soundings in this neighbourhood as well as in the narrow part between the island of Kambing and Portuguese Timor and the straits between Kambing and Alor. By this means we determined the depth of the sills separating the Sawoe sea from the Banda basin and the Wetar basin, lying east of the island of Kambing, and the analysts gained a day of rest by a temporary stoppage in the flow of water samples to the laboratory. The deepest communication with the Wetar basin proved to be 2100 m; the sill between Alor and Kambing lies much higher, viz. at 1260 m; the one in the west between the island of Soemba and Flores at fully 900 m.

Through the straits between the islands Flores and Wetar pass the sperm whales which migrate from the Indian Ocean through the Banda sea to the Pacific Ocean, whence they return. Prof. Weber, when visiting a village on the island of Lomblen during the Siboga-expedition, saw there many skulls of whales which had been captured by the inhabitants in the Sawoe sea. According to Boschma ¹⁾ the largest specimen which was accurately measured had a length of 25.6 m.

After the whole area had been sounded and sufficient data collected concerning the bottom configuration and the depth of the sills, oceanographic investigations were carried out on both of the eastern sills, st. 161 and 152, and research in the Sawoe sea was concluded on Dec. 17th by the last deep station 163. From here we sailed through the Pantar strait into the Banda sea, where the hill sides, a few weeks ago all brown and withered, were now, after the break of the moist west monsoon, clothed in the fresh green of the Indian spring.

On Dec. 18th the first observations were carried out in the Banda sea at st. 164 to a depth of about 4000 m. While making constant depth-determinations we steamed towards the west. It was my intention when we had reached the island of Madoe to continue south to the island of Paloë to acquire still more data concerning the bottom configuration of the Flores sea, detail chart 8, with an eye to a proper distribution of the stations along a cross-section when it should be the turn of this area to be investigated. However, lack of time forced us to pursue our course to the Postilion Islands, thus crossing the two sounding tracks on the journey to and from Makassar at right angles.

In the forenoon of Dec. 20th we came to Pelokang the most eastern island of the south-western group. Oceanographic research in the neighbourhood of this island stood on our programme, combined with a research on shore and on the coral reefs by the biologist and geologist. After a brief reconnoiter on shore we passed on to the island Sapoea Besar and anchored there towards evening.

The following morning Boschma and Kuenen disembarked, while a motor boat and two flats were sent with them under command of Lieut. Milo. December 21st and 22nd were devoted to observations on a cross-section between the islands of Sarege and Sangeang, 165—169, to which observations at st. 170 on the rise of the sea floor we had found were added. When this was accomplished we returned to Sapoea Besar, where the shore-party returned on board on Dec. 23rd.

¹⁾ H. Boschma. On the teeth and some other particulars of the sperm whale. *Temminckia*, Vol. III, 1938, p. 253.

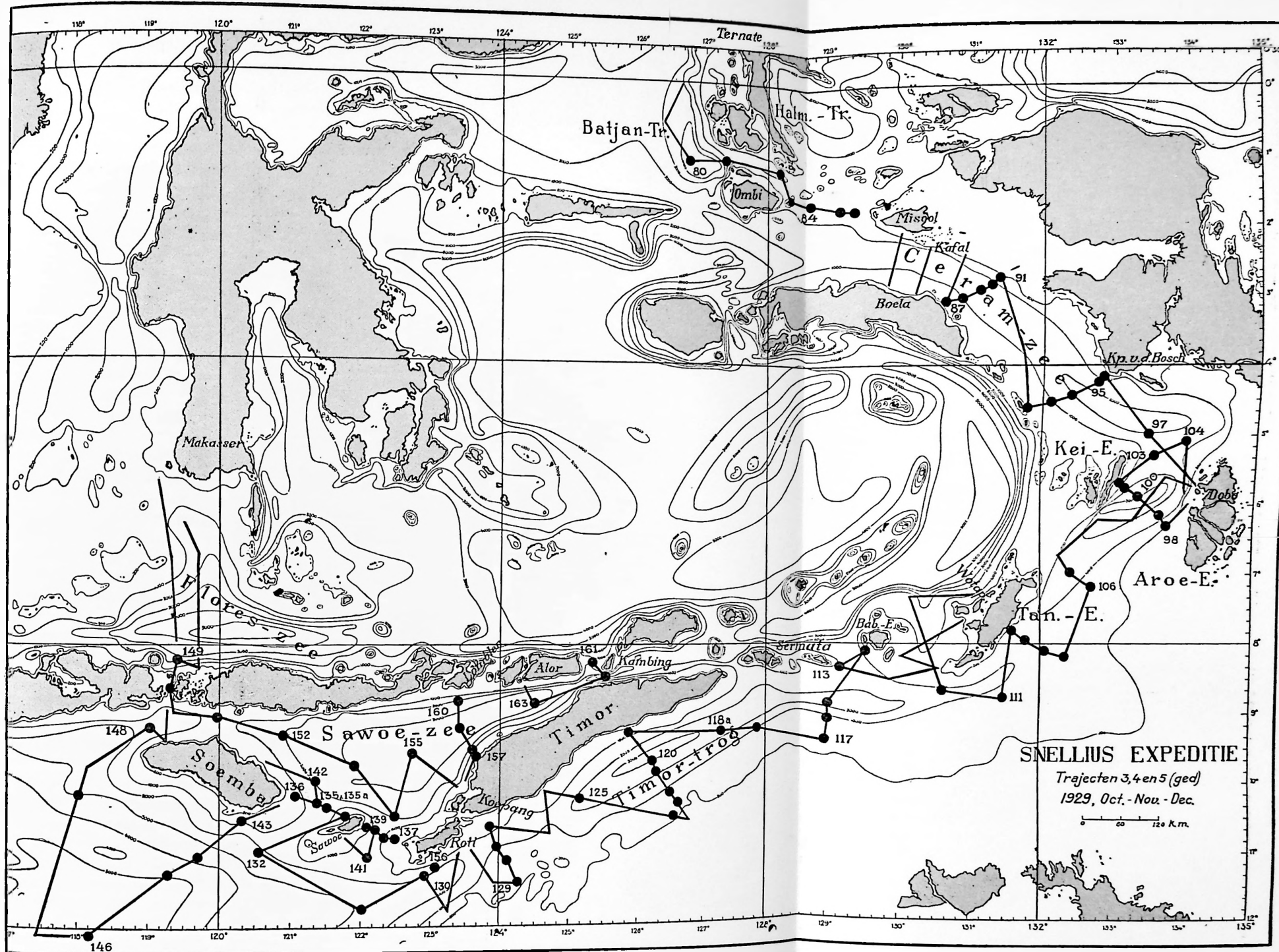


Fig. 7. Stations on the 3rd, 4th and part of the 5th track. Previous representation of the bottom configuration.



The following day we steamed to the Bima bay, pursuing a fourth sounding track in the Flores sea. Considering the complicated configuration of the sea floor here it was desirable to obtain as many depth-determinations as possible.

In the quiet bay of Bima we celebrated Christmas under unfamiliar circumstances. When leaving Holland my wife had brought with her some ingredients for giving the mess-room a cheerful Christmas-aspect. The absence of holly and mistletoe luckily did not damp our good spirits. On Dec. 27th the journey to Soerabaia began, where we were expected on Dec. 29th. On our way, on Dec. 28th we were able, thanks to the excellent look out that was held on the bridge, to come to the rescue of two natives who were drifting in a broken fishing boat far from land.

Weather conditions were generally speaking favourable, only when passing the straits of Alas and Lombok through which there was a strong wind blowing from the south, was any trouble caused by sea disturbance. The latter made the progress of the ship slower than had been reckoned on in settling our programme, so that a final sounding track at right angles to the isobaths was obliged to fall out. On the date arranged we anchored in the roads of Soerabaia and on Dec. 30th moored in the Naval Docks, plate XXI.

The personnel of this establishment carried out some repairs on the sounding and serial machines, after which their drums were provided with new wire. All instruments were thoroughly cleaned and overhauled by the ship's personnel, so that we might expect everything to continue to function properly during the rest of the research. Hamaker for the second time verified the zero's of the reversing thermometers at Pasoeroean (see p. 21). Here too Boelman had an opportunity for comparing the colorimetric method of determining the hydrogen-ion concentration of the sea water with the electric one. The leader of the expedition held consultations at the Naval Department at Batavia about their taking over the instruments and apparatus after the conclusion of the expedition. I owe many thanks to Mr. and Mrs. S. W. Visser for their kind hospitality given to me during my stay there.

By making use of the air line I had for the first time an opportunity to realize the great advantages of travelling by air in the tropics. As fresh as I started the trip at Soerabaia I alighted within four hours at the aerodome Tjililitan (Batavia) after a short stop at Semarang. Moreover I had the pleasure of admiring the beautiful scenery below with the row of high volcano's on the left.

During the 5th track the following physical-chemical determinations and wire soundings were carried out:

	t	S	O ₂	A	pH	Wire soundings
Serial observations.	446	454	356	54	401	22
Surface observations	164	159				

Plankton from the surface was obtained by Boschma at almost every station; vertical catches with the large tow-net were carried out once, horizontal catches from the deeper layers with the large tow-net 3 times. Valuable biological material was collected during the first cruise at several places, from the shore and the reefs, by diving or by using a dredge in shallow water.

A large quantity of geological material was obtained by Kuenen during his numerous investigations ashore and on the coral reefs. Moreover 19 bottom-samples were collected during the fifth track.

During the research Hamaker, assisted by the torpedo petty-officer, plate XIV, had bestowed great care upon the functioning of the instruments and apparatus, keeping them always in strict repair. The reversing thermometers, which were used in pairs, were constantly changed about, so as to compare one instrument with another and to test their reliability. Great care was bestowed upon the checking of the surface thermograph and the correct adjustment of it, so that, even when the ship was rolling, accurate observations of the surface temperature could be obtained. He devoted much time to the comparison of the observations with barograph, thermograph and hygrograph, with barometer and Assmann's psychrometer observations. Moreover the meteorological observations obtained by the registering instruments of Fuess were compared to those of Richard, which showed that a correction was needed in the Fuess hygrograph (Vol. III).

A comparison of the surface temperature observations made with the thermograph with those

obtained with the reversing thermometer and by the ordinary bucket method, furnished an idea, not only of the functioning of the thermograph, but also of the reliability of the bucket observations. (Vol. II, Part 4).

The automatic brake of the two serial machines was arranged so that as the motor stopped when hauling in, the machine stopped quickly too. The port machine (steel wire) was used for profound depths, the starboard machine (aluminium bronze wire) for depths less than 4000 m. Care must be taken that the machine is not touched by salt water (spray water or when washing the deck) as this causes rust to accumulate on the mobile parts in a few days of rest. A control measuring-wheel, which can be easily seen from the place where the electromotor is manipulated, is highly desirable.

The reversing thermometers need great care; an after-flow of the mercury occurred now and then in some of the instruments, which, occasionally after they had been put out of use for some time, became reliable again. The accuracy of the temperature data however, does not depend only upon the good working of the instruments but also upon the correct estimation of the depth at which the observations are made. Further particulars concerning the instruments will be found in Vol II, Part 1.

D. SECOND CRUISE

a. SIXTH TRACK, SOERABAIA-MAKASSAR. JAN. 28th—FEB. 24th, STATIONS 171—199.

As there was a good deal of sickness on board our departure which had been fixed for Jan. 21st was postponed for a week, and for the health of those on board this time was spent in the roads. After the Inspector of the Shipping Department of the Navy had looked over the instruments which we hoped would be taken over, we took the sea through the Eastern Entrance, for the continuation of our research. We began with the shallow station 171 in Madoera strait.

In connection with the expected weather conditions, our general programme of work was arranged so that the area to be examined would lie to the north of the Lesser Soenda Islands: Bali, Lombok, Soembawa, Flores. During the change of the monsoon the less quiet Banda sea would have its turn, while the month of May was considered to be the best time to start our research in the neighbouring Pacific Ocean. The return journey to Soerabaia in June and July would be made use of to finish off the research in the Celebes sea, and to repeat the observations at certain stations there and in Makassar strait.

The first deep station in the Bali sea was not very fortunate; the sounding wire broke (at a joint) by which we lost an Ekman tube, a new pattern reversing bottom water sampler and a protected and unprotected reversing thermometer. Proceeding eastwards along the axis of the Bali basin, then in the narrow channel connecting the basin with the Flores sea and finally in the western part of this area, observations were carried out at stations 173—175.

After station 176 north of the Paternoster Islands had been accomplished on Feb. 1st, we were obliged to put in to Makassar, on account of the serious indisposition of the medical officer, Mr. Broekhoff, who was accordingly taken up in the Military Hospital the following day. The leader of the expedition, suffering from an attack of fever also remained in Makassar, so that for the time being all responsibility for the expedition devolved upon Commander Pinke.

After Boschma and Kuenen had paid a visit on Feb. 3rd to some islands of the Spermonde Group, lying opposite Makassar, and the fuel had been replenished the ship again took to the sea for observations on an oceanographic section across the Flores basin, stations 177—182, where the greatest depth of about 5000 m was found at station 180, detail chart 6.

On our way to the Paternoster Islands we passed a shallow of 82 m on the Ivry shoal, where a bottom sample was raised, station 182 *l*. We anchored in succession on the afternoon of Feb. 7th and 8th to the south of the island of Aloang and near the island of Sailoes, to give the geologist and biologist an opportunity for collecting material in the neighbourhood of these islands and to allow the crew a day of rest on Feb. 9th. The following day the anchor was weighed and course was set to station 183 with the intention to carry out observations at three stations in the area north-west of the Postiljon and Paternoster Groups.

The west monsoon, which so far had been accompanied by only a few squalls, now made itself

felt in its least pleasant form, so that at station 183 the ship could only be kept in place with great difficulty, owing to the heavy seas and the north-westerly gale. We therefore abandoned observations at the following station to the north-west, and turned our course to the east, to station 184. The bad weather here also prevented our depth-determinations, intended for comparing the results obtained by wire soundings and echo-soundings at depths from 300 to 500 m. After completing station 184 we returned to the roads of Makassar, which were reached at midnight on Febr. 11th.

The following morning the leader came on board again, and on Febr. 13th we set out once more to make our observations at station 185, in amplification of stations 177 to 183. This completed the second oceanographic cross-section in the Flores basin.

Research in the area south of Celebes was begun on Feb. 14th, after passing Salajar strait, with the observations at stations 186 and 187 in the Salajar trough. To the west of Salajar the weather was still squally, with a moderate south-westerly swell; on the east side of the island the wind and surface conditions were much improved, so that the above mentioned stations and those in the Gulf of Bone and in the area to the south (st. 188—193) were accomplished under favourable conditions. Under these circumstances the large Ekman tube of 4 metres length was used, which brought up bottom-samples from a depth of about 2000 m of 168 and 174 cm respectively. It should here been mentioned that this heavy sampler is not provided with a glass inner tube. This fact, combined with the circumstance that the Sigsbee lead (of which the core-tube is not provided with a glass inner tube either) yielded samples of a mean length equal to those of the heavier ordinary Ekman-sampler, gave Hardon the idea of using the last mentioned instrument without a glass and copper inner tube. The results that Kuenen obtained after this answered to the expectations. While the length of the samples with the original arrangement averaged 45 cm they afterwards reached about 60 cm.

Except in two samples, there was an entire absence of stratification; even the two long samples showed only a gradual darkening of the colour of the deeper layers, as was usually the case in the other areas as well.

Navigation at night more than once caused difficulties and put a great responsibility upon the Commander and his staff. During the observations the ship had usually drifted to an unknown extent, so that its position could not be exactly fixed at night. This was the case, for instance, when we sailed from station 192 to the reef of Taka Garlarang, and we were obliged to wait for daylight before we could approach the reef.

According to the existing depth chart by Tydeman we had sounded the *deepest* entrance to the Gulf of Bone at and near station 193. The greatest depth we found on the sill was 2180 m. But the remarkable thing was that this did not tally with our observations concerning the properties of the sea water on the inside, Gulf of Bone, and those on the outside of the sill, S.W. Banda basin.

We found for the temperature:

Depth	Gulf of Bone	S.W. Banda basin
2500 m	3°.095 C	3°.090 C

As the same temperature prevails in both areas it is evident, that anyhow down to this depth, they must be in direct horizontal connection with each other. This connection could lie between the islands of Kakabia and Kalao where the existing chart, however, gave a depth of less than 2000 m. Later we did actually find there a narrow passage with a depth of approx. 3300 m. See p. 131.

Feb. 17th we sailed from Kakabia in a south-westerly direction to the deep station 194 and from there to the small island of Paloë to the west, detail chart 8. In this region and at the last named station we experienced a strong easterly current. As we approached the north coast of Flores, the sea disturbance and the short swell gradually subsided. The wind was mostly south-west, varying in strength and direction.

Between the islands of Paloë and Madoe, the fourth oceanographic cross-section, stations 195—198, terminated the research in the Flores sea; at station 197 we found a depth of about 5100 m. The track on the route map or detail chart 8, in which the drifting of the ship at the last mentioned station becomes very evident, shows that there was a strong easterly current; the observations at st. 197 lasted from Feb. 19th 18 o'clock to 3 o'clock next morning.

After station 198, the numerous echo-soundings on the route to the north coast of Flores and back to the island of Kalao gave a very welcome supplement to the depth-determinations, completing the data on the configuration of the bottom of the Flores sea. Again the profoundest depth was found to be about 5100 m. A comparison of our results with Tydeman's chart, shows that the latter gives on the whole a very good representation of the actual conditions, but we were able to supply numerous supplementary details. The network of soundings over the Flores sea is fairly fine, which is needful in connection with the complicated bottom formation. The part deeper than 5000 m is in the form of a trough, about 120 sea miles long and only 7 sea miles broad. (See depth charts, Vol. II, Part 2, Ch. II).

On Feb. 21st we sailed to the island of Tana Djampea and anchored there in the roads of the native village of Katella (Benteng), where we remained at rest next day. Boschma and Kuenen took advantage of the opportunity for examining the neighbouring reefs and islands; in the laboratory the remaining water samples were titrated.

Sunday Feb. 23rd anchor was weighed. After a sounding track across the southern part of the Salajar trough, the last observations were made at station 199 in the southern entrance to the trough between the islands of Salajar and Tana Djampea. This concluded the sixth track.

Notwithstanding the interruption in the research caused by our forced visit to Makassar, we were able, thanks to the hearty co-operation of all concerned, to carry out our established programme, with the exception of an occasional station. As might be expected at this time of year, the weather was not always equally favourable. Moreover clouds and squalls laid particular difficulty in the way of astronomical determinations of the ship's position, while accurate dead-reckoning was also impossible because of our unfamiliarity with strong, constantly changing surface currents.

When, on Feb. 24th, the anchor was dropped in the roads of Makassar, our medical officer returned on board, fortunately completely restored to health. During our stay there, the Governor of Celebes, Mr. Caron, very kindly put a motor boat at the disposition of the geologist and biologist, so that they were able to spend a few days examining the islands and reefs opposite to Makassar.

b. SEVENTH TRACK, MAKASSAR-TERNATE. MARCH 4th—27th, STATIONS 200—227.

On this track we investigated the western portion of the Banda sea, as well as the important entrance to it between the islands of Boeroe and Sanana and the entrance to the Boeroe sea between the Soela Group and the island of Obi Major. After we had celebrated the Javanese new year at Makassar, we left the roads on March 4th and sailed to the Salajar strait. In the area to the east of Salajar a few supplementary soundings were made, while at the same time we completed the oceanographic section between the islands of Salajar and Kabaena by observations at station 200 on the ridge which borders the Salajar trough on the east side, stations 186, 187, 200, 192, 188. We then steamed eastwards and on March 6th came to the north side of Batoe Ata, an island which had attracted our attention during our last track, by its peculiar terrace formations. Here the ship lay for that day, to give Kuenen an opportunity for reconnoitering the ground on shore.

The weather conditions were on the whole favourable, with north-westerly to south-westerly wind, occasionally rising in strength, with increasing sea disturbance.

On the way to the Toekangbesi islands, detail chart 9, a ridge was found, after which the depth again increased in the Boetoeng trough. March 7th we examined the area north-west of Binongko, after which Boschma and Kuenen disembarked on the island. The motor boat and the two flats, under command of Lieutenant Perks were left behind for the research.

The ship left the same day for the south. It was expected that the soundings would again reveal a deep part (Boetoeng trough) which would be followed by a ridge upon which our next station would come to lie. This, however, proved not to be the case, so that, after it had been ascertained that the depth remained at about 3800 m we sailed back to the north and carried out oceanographic observations to a depth of about 3000 m at station 201, as the first of 4 stations on a cross-section between the islands of Binongko and Komba in the extreme western part of the Banda sea, stations 201—204. At station 201 we spent some anxious moments during the hauling in of the bottom-sampler, when the dial of the dynamometer which was always attached to the sounding wire, registered a tension of 150 kg, the breaking point of the new wire being 180 kg. Fortunately all went well, the sampler contained a sample of tough clay of only 20 cm length.

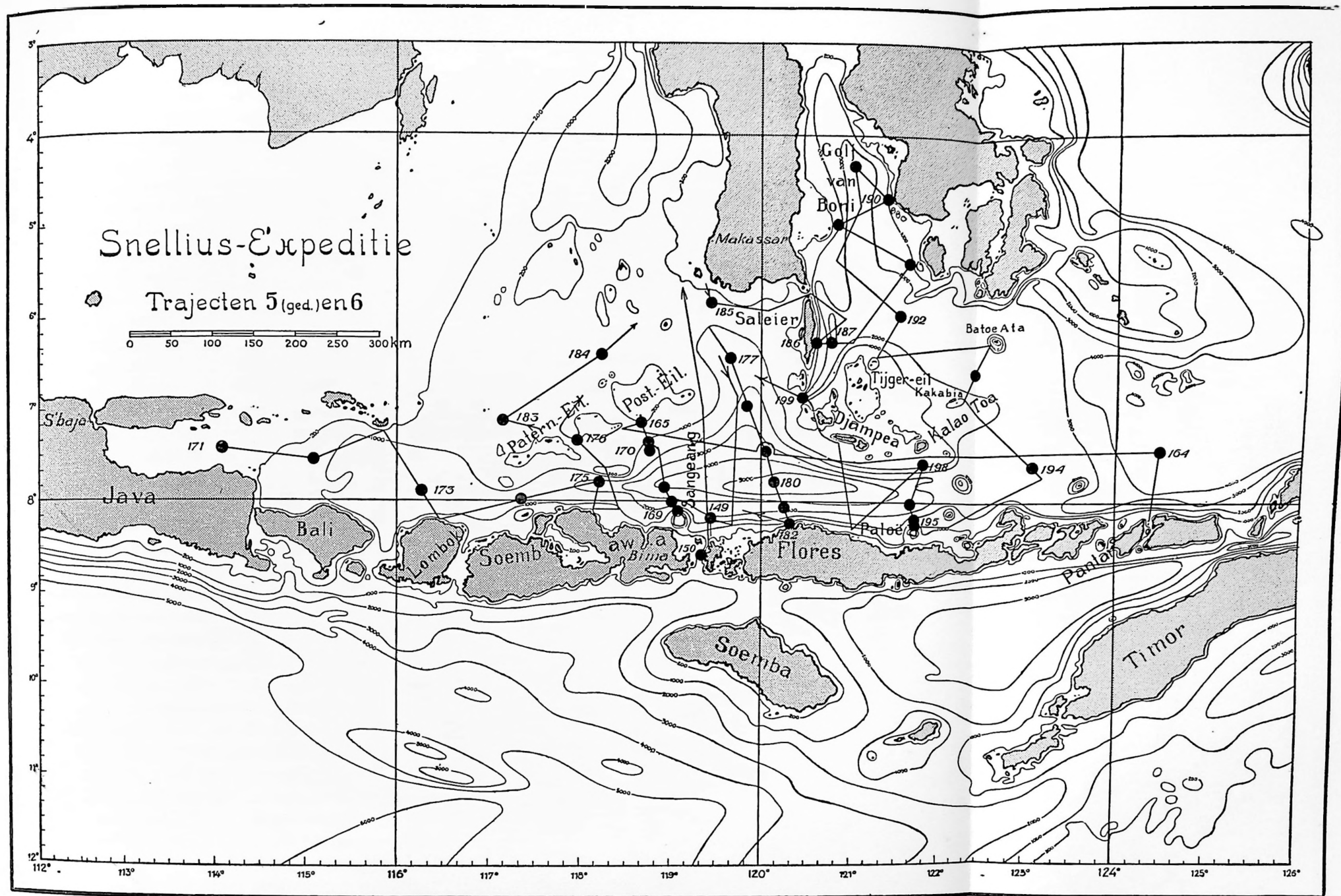


Fig. 8. Stations on the 6th and part of the 5th track. Previous representation of the bottom configuration.



On March 8th at station 202 (3900 m) an attempt was made to collect data on the properties of the sea water near the bottom, at a distance of about 30, 60 and 90 m. For this purpose a Sigsbee lead, 25 kg, was attached to the lead line of 30 m and above this line 60 m of 4 mm stranded wire, followed by the ordinary piano wire of 1 mm. The upper water bottle, 90 m above the bottom, was a reversing bottom water sampler, below this at a distance of 30 m and 60 m a Nansen water bottle, commonly used for serial observations was attached.

Hamaker had thought out a contrivance by which the bottom water bottle ¹⁾, after being reversed, released a messenger which caused the uppermost ordinary water sampler to reverse, which in its turn acted upon the lowest one. The result, however, was not satisfactory. Apparently after the weight of 25 kg had been released from the Sigsbee lead the tension in the wire rope of 4 mm was no longer great enough so that it kinked and one of the messengers got caught, while the thermometer of the second water sampler suffered an after-flow of the mercury. The bottom water sampler gave a temperature of 3°.13 C., the two upper water bottles both gave the same values for salinity and oxygen, viz. 34, 16‰ and 2.39 cc/L.

When the cross-section was completed we sailed to station 205 (4000 m) where the same method was pursued with the wire sounding. This manoeuvre was more successful, but unfortunately the lowest thermometer did not function properly. The salinity proved to be constant in the three niveaus, 34.61‰, the oxygen was 2.37, 2.45 and 2.33 cc/L respectively; the temperature at 90 and 60 m above the floor showed very small differences, mean value 3°.14 C.

On March 9th we all dined together in the mess-room to celebrate the day on which we had left Holland a year ago. Steaming back to Binongko we sounded on the Nieuwekerk rise, where, however, we did not find any lesser depth than was given on the chart. No ridge having been found on the track to the south, as recorded above, the four stations between the islands of Binongko and Komba had to be supplemented by a fifth (206) in shallow water to complete the section.

When the station was completed we sailed to the south coast of the island of Tomea with the purpose of anchoring there, but the anchorage near to a precipitous coast being very bad the Commander did not consider this would be wise. After the landing-party had returned on board and the motor boat and two flats had been hauled up, we sailed out at about sunset, towards Boetoeng. Here we lay for the following day, for rest and a little exercise.

On March 12th at 6 a.m. anchor was weighed and we sailed back to the Toekangbesi islands; a series of soundings across this area, detail chart 9, gave us a preliminary knowledge of the bottom configuration there. On the rise which extends from the island of Roendoeman in a W.N.W.-ly direction observations were made; station 207, depth about 1200 m. This ridge is separated from the islands to its south-west by a deep channel of fully 3000 m.

Station 207 was the first of a cross-section between the Toekangbesi islands and the island of Boeroe, st. 207—211. The weather was good on the whole, the approach of the change of the monsoon could already be felt. Instead of westerly wind with squalls and rain, there were light to moderate north-easterly to easterly winds, accompanied now and then by a light and short easterly swell.

At station 209, three observations were again carried out at a short distance from the bottom, to ascertain if the properties of the sea water underwent rapid changes here. After the experiences of stations 202 and 205 we decided not to combine these observations with ordinary wire soundings and not to use any sounding tube or bottom water sampler, but a heavy weight and ordinary Bergen-Nautic Nansen water bottles.

For these observations we used the stranded steel wire of 4 mm diameter of the serial machine with a hempen line of 10 metres length, attached to the end of it and bearing a weight of 60 kg. At the end of the steel wire hung also a weight of 10 kg to keep the wire taught in case the weight of 60 kg should come to rest on the sea bottom. The ordinary water samplers were attached to the wire at about 20, 50 and 80 m distance from the lowest weight. The lowest water bottle was provided with two protected thermometers.

It was beautiful weather with a smooth sea. With the help of the dynamometer the moment at which the heavy weight reached the bottom could be clearly observed, the water samplers were reversed by a messenger in the usual way, the result was as follows:

¹⁾ Afterwards a reversing thermometer frame.

Depth	Temperature	Salinity	Oxygen
4142 m	3°.12 C	34.61 ‰	2.53 cc/L
4172 „	3°.13 „	34.61 „	2.43 „
4202 „	3°.13 „	34.61 „	2.53 „

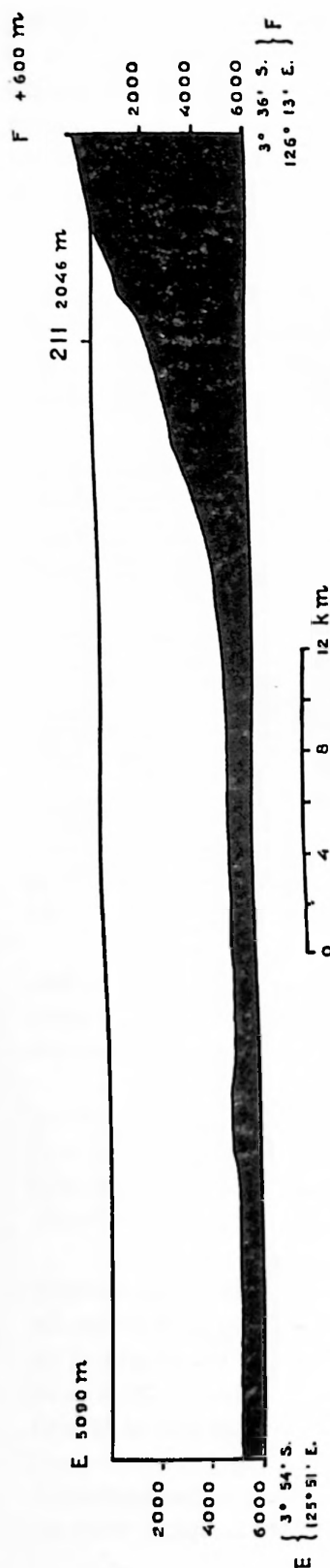


Fig. 9. True-scale bottom contour off the S.W.-coast of the island of Boeroe. (Banda sea).

The temperature is thus constant, the slight difference lies within observation errors; the oxygen alone, shows at 50 m above the bottom a slight variation, which is probably due to some error in the treatment of the sample or in the titration.

Observations at stations 202, 205 and 209 had shown something else, namely that in the pH -determinations the samples from the reversing bottom waterbottles by Marx & Berndt abnormal values (too high) were constantly yielded, probably due to chemical action. The internal spring showed a trace of verdigris and on the inner side of the tube a few dull patches were visible. The confirmation of what was already suspected was far from pleasant. However Hamaker and the torpedo petty-officer contrived a better arrangement, by which the ordinary water sampler hanging below it was made to reverse. In this way we were assured in future of a reliable bottom water sample.

At the last station, lying close under the coast of Boeroe, 211, we found a depth of still 2000 m. The steepness of the coast appears from fig. 9; the sea bottom becomes fairly even at a distance of about 15 km from the shore. March 15th we sailed again west and worked station 212 in the middle of the northern Banda basin. The depth here was fully 5000 m; as the observations with the vertical plankton net alone occupied about 5 hours *we spent 14 hours* at this station.

We steamed on in westerly direction to the island of Manoei, which came into sight early in the morning of March 16th. Between this island and Taliaboe, belonging to the Soela Group, a second cross-section was made at the stations 213—217. The greatest depth found was 5000 m.

On March 18th H.M.S. Snellius anchored in the Vesuvius Bay, to the north of Pasi Ipa, a small island near the S.W. point of Mangole. Here Boschma and Kuenen were able to make observations and collect material in the neighbourhood of the anchorage, the laboratory could work through a part of the large supply of water samples, and as far as was possible a well earned holiday could be enjoyed by those on board, plate XXV.

After the last station 218 in the northern Banda basin was completed on March 20th, we sailed to the N.W. point of Boeroe. Before fixing the four stations for a cross-section between this island and Sanana, the area was carefully sounded, detail chart 10. Subsequently the usual observations were made in this deep entrance to the Banda basin at stations 219—222.

No less time was then devoted to the sounding of the passage between the island of Obi Major and the Soela Group, detail chart 11. The depth of this sill, about 1900 m, is responsible for the properties of the sea water that flows into the Boeroe sea from the Pacific. This water subsequently reaches the Banda sea after passing through the much deeper passage between the islands of Sanana and Boeroe.

After sufficient data had been obtained of the bottom configuration in the passage the oceano-

graphic observations on the cross-section were carried out at the stations 223—226, which were supplemented on March 24th by those from station 227 lying in the Molukken sea, north of the strait, detail chart 11.

To get a preliminary idea of the very uneven bottom configuration of the Molukken sea, which was considered advisable in view of the distribution of the stations which were to be held in September, we steamed over the area taking two series of soundings across it, to Ternate, where we arrived towards the evening of March 27th. On this track and during our stay at Ternate, the analysts were able to catch up with their remaining work.

After leaving the Banda sea we still enjoyed calm weather. The days spent at Binongko had unfortunately given Kuenen and Boelman who had accompanied the landing-party an attack of malaria, which manifested itself a few days before our arrival at Ternate.

During the sixth and seventh track the following physical-chemical determinations and wire soundings were carried out.

	t	S	O ₂	A	P _H	Wire soundings
Serial observations	1239	1250	889	159	808	60
Surface observations	319	307				

As in the preceeding tracks, plankton was collected from the surface at almost every station, usually with nets of various sizes of mesh. Horizontal catches from the deeper layers with the large tow-net (straminpose) were carried out 8 times; this net and the vertical closing net were used 6 times for vertical catches. The wire soundings yielded 56 bottom samples of various lengths. Concerning the investigations ashore, on the reefs and in shallow water, the writer refers to Ch. IV of this volume and to Vol. V, Part 2 and Vol. VI.

The care and supervision of the oceanographic and meteorological instruments gave Hamaker a good deal of work. Some of the reversing thermometers worked badly owing to an after-flow of the mercury, or from the mercury column not breaking off at the proper place, or because it did not break off at all. The obviation of these defects costs a deal of time; sometimes the errors were found to disappear after a period of rest. After it had been seen that the bucket observations from the bridge gave results that were too low, the registrations by the surface thermograph were always checked by observations with the reversing thermometer made in the neighbourhood of the resistance thermometer.

During our second stay at Ternate, many kind marks of attentions were paid to us, showing that the settlement there were anxious to make our days of recuperation as pleasant as possible. Speaking for my wife and myself I know that we shall always look back with gratitude and pleasure upon the great hospitality offered us by the Resident and his wife, Mr. and Mrs. Hovenkamp, in their own house.

c. EIGHTH TRACK, TERNATE-AMBON. APRIL 3rd—MAY 1st, STATIONS 228—253a.

When on April 3rd we again took to sea, we had just completed all our chlorine titrations. After weighing anchor at 6.30 a.m. we sailed south between the chain of volcanic islands and the west coast of Halmahera. Here the depth observations from the two echo-sounding machines (Hughes & Atlas) were compared with each other and with the wire soundings to a depth of about 400 m; see Vol. II, Part 2, Ch. I.

The eighth track was principally concerned with observations in the central part of the Banda sea and current observations in the passage between the Soela islands and Obi Major, Lifamatola strait, where the water from the Pacific Ocean flowing into the Boeroe sea over a sill at about 1900 m depth, finally reaches the Banda sea.

Having entered the Molukken sea our ship steamed to the strait, to begin oceanographic research in the south of it at station 228, detail chart 2. The weather, which had become unsettled during our stay at Ternate, bringing a great deal of rain, was not improving. Moreover there was a slight

swell coming from the north. After the usual observations were completed in the Boeroe basin at station 229, depth approximately 5200 m, and in the northern entrance to the Manipa strait (st. 230) we steamed through the strait to the Banda sea, where to the south of the island of Ambon we completed st. 231 on Sunday April 6th, detail chart 12. In the afternoon of that day, we entered for the first time the magnificent bay of Ambon, to send off our mail. To the surprise of us all, we found a mail from home awaiting us there, which we had not expected to receive till three weeks later, at the conclusion of the track, plate XX.

That day we remained at anchor before Ambon and put out the next morning. Observations were made, following on to st. 231, in a cross-section which traversed the Siboga ridges and extended from Ambon to the volcanic island of Seroea (st. 231—237). It proved to be a monotonous and fatiguing piece of work, as the stations were pretty close together and the depth often varied from 3000 to 5000 m. On this section, in the wire sounding very successful use was made of a reversing bottom water sampler provided with a better arrangement for reversing the ordinary sampler hanging below it, after hauling in the wire. This arrangement secured us a pure bottom water sample. The greatest depth at which we made observations was about 5100 m at station 235. At the following station both the bottom water sampler and the ordinary water sampler hanging below it were provided with a protected and an unprotected thermometer. This provided a check upon the accuracy of the thermometer depths; the difference amounted to 15 m at a depth of 3600 m. At station 236, with the serial observations, three Nansen water samplers were hung close below one another, each provided with a protected and an unprotected thermometer. The difference in reading gave for the three sets the same thermometer depth, namely 1997 m. An excellent result!

On April 10th we sailed between the island of Seroea and the small island lying to the west of it. It was our intention to anchor there to give Boschma and Kuenen an opportunity for examining the island of Seroea. Anchoring however, proved impracticable on account of the depth near the precipitous coast, so that the ship remained under steam. It was a surprise for the visitors to this small volcanic island to find a civilized population; the schools established by the mission have greatly contributed to this result, plate XXII. In various spots on the slope we saw sulphur vapours arising and the highest peak was, in fact, of a completely yellow colour.

We sailed in the direction of the Lucipara islands and made observations in the centre of the basin at approximately 5000 m depth, followed by the 2nd cross-section between this group of islands and the island of Damar, where depth variations from 3000 m to 5000 m were found (stations 239—243). At station 240 the piano wire broke at a strain of 140 kg according to the dynamometer, by which we lost an Ekman bottom-sampler, 3 reversing thermometers a Nansen and a bottom water bottle, provided with an arrangement for reversing the water sampler hanging below it, as well as 3200 m of wire.

The weather was less favourable. Wind E.S.E. to S.E., force 4—5, rough sea and short southeasterly swell. This indicated the approach of the east monsoon, but the rain showers which passed over us from the east, belied it. The direction of the surface current was apparently in the opposite direction to the wind, which gave rise to a very troublesome sea disturbance.

After we had made observations in this cross-section at depths varying from 3000 to 5000 m we stopped on the night of April 12th near the coast of the island of Damar to make oceanographic observations down to a depth of 1500 m at st. 243. This was an unlucky station. While the sounding wire is being wound up it is dried by holding a rag round it all the time and now a joint passing by caught the rag and carried it along to the measuring wheel. After this had been redressed the winding was continued, but when the wheel registered still 50 m out the joint between the piano wire and the hempen line ran up against the wheel, breaking the line, and a Monaco-catcher, a bottom water sampler and two reversing thermometers were lost. Apparently the measuring wheel had not registered for the few moments that the rag was stuck in it, while wire was still being reeled in. It is very important that during the reeling in of the sounding wire the indications of the measuring wheel should be constantly watched so as to be able to give warning when a joint comes up out of the water. The joints cannot be examined often enough. It is much better never to use wire that has been jointed, this is really only a bad economy ¹⁾. Again we had lost several valuable instruments. We

¹⁾ Although we had ordered piano wire of 10000 m length in one piece the firm Felten & Guillaume had delivered it in three lengths.

were getting short of unprotected thermometers and modern bottom water bottles, we had only two of the latter left, and I wanted to keep these for the Pacific. So we used a Nansen water bottle and a reversing thermomeferrame, the latter being modified so that after the reversing of the thermometers it released a messenger which reversed the ordinary water sampler hanging below it. The last functioned, thus, as bottom water sampler.

That day (Sunday) we tried in vain to find a suitable anchorage, so we sailed to the S.W. point of the Siboga ridge. From here, to the island of Wetar the ordinary observations were made along a cross-section consisting of the stations 244—247. The wind was still moderate to strong coming from the S.E. and the sea disturbance became less troublesome as the current and wind flowed in about the same direction. For the last few days there had been no rain; the weather became more and more propitious, while the south-easterly swell subsided and gradually disappeared.

On April 14th a great number of soundings were taken round about the island of Goenoeng Api (Goenoeng = mountain, Api = fire) showing very clearly how this massive volcano rises up precipitously from the sea floor at a depth of from 4000 to 5000 m so that only its uppermost part is visible above the sea level, plate XXVI and figure 10. While this work was being done, Boschma and Kuenen were busied on shore collecting data.

The following day we set our course from station 247, north coast of Wetar, to the eastern extremity of the submarine plateau which extends eastward from the Toekang Besi Group. When our observations here were completed and the position of the S.W. spur of the Siboga ridge had been ascertained by extra soundings, from April 16th to 18th the oceanographic profile running from north to south was completed between the islands of Wetar and Boeroe, stations 249—252. South of Boeroe we found to our surprise, where according to Tydeman's chart there should be a depth of about 4500 m, the depth rapidly decreasing to about 800 m. On this ridge an extra station was inserted, st. 250, at a depth of 1000 m. From here to the island of Boeroe we again found depths exceeding 5000 m.

In the period from April 5th to 17th the plankton-catcher was lowered almost every day to a depth of about 2 metres below the surface between 10 a.m. and 1 p.m. and between 9.30 and 10.30 p.m. At the same time a water sample was obtained from the locality from which the plankton was collected to investigate the phosphate contents of the water and its correlation with the plankton amount. For the results we refer to Vol. VI, Biological data, p. 4.

As at station 211, off the south coast of Boeroe, at station 252 the absence of the normal sedimentation was again recorded; the bottom catcher here again brought pebbles up from a depth of over 1500 m. The cause of this may lie, as on the sills between the basins, in the presence of a fairly strong current running at a great depth along the south coast of Boeroe; the presence of such a current was indicated by the strong incline of the piano wire during the sounding. Kuenen also suggested the possibility of a submarine land-slide, fig. 9.

After observations had been made in the Manipa basin at st. 253, detail chart 12, to a depth of 400 m the ship reached Ambon on April 19th, the birthday of H.R.H. the late Prince Hendrik, where we spent Easter.

The first week after leaving Ambon on April 22nd was occupied by serial and current observations in the passage between the Soela islands and Obi Major (Lifamatola strait, see detail chart 11).

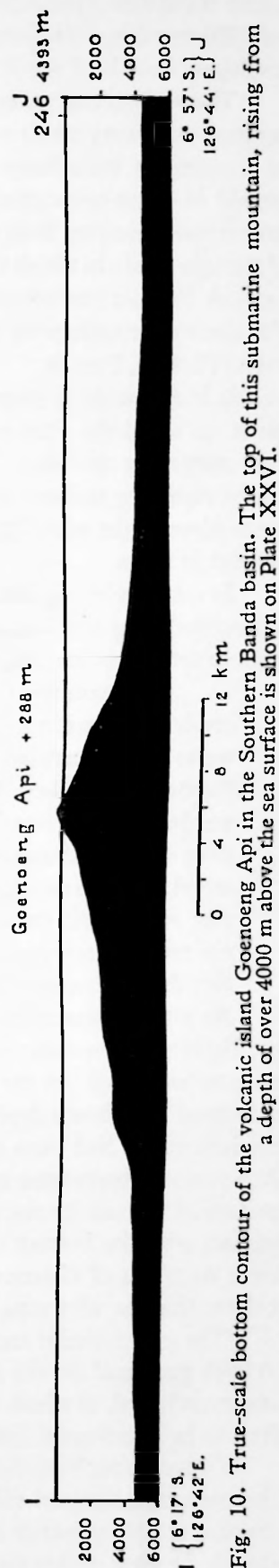


Fig. 10. True-scale bottom contour of the volcanic island Goenoeng Api in the Southern Banda basin. The top of this submarine mountain, rising from a depth of over 4000 m above the sea surface is shown on Plate XXVI.

Boschma and Kuenen spent the time in Obi Latoe, a little island lying north of Obi Major, where they were put off on April 23rd with the indispensable motor boat and two flats under command of Lieut. Veldman. The same day the ship anchored at st. 253a towards evening, at about 1800 m depth on 2500 m cable, a manoeuvre which occupied two hours. The observations, which were begun immediately lasted till April 27th without stop.

These observations consisted in the collecting of water samples and the determination of the temperature every two hours at depths of 0, 50, 100, 150, 250, 450 and 800 m. The temperature of the samples, the salinity and the oxygen contents were determined, to study the changes that occurred in these properties. At the bottom of the line a weight of 57 kg was hung; to the middle and lowest water sampler both protected and unprotected thermometers were attached for determination of the true depth in which the sampler hung, the weight of 57 kg not being sufficient to keep the series vertical. Further current observations were made at a depth of 0, 50, 100, 200, 350, 500 and 1200 m. For these observations we again used the serial winch with the aluminium bronze wire of 4 mm diameter (Vol. II, Part 3).

It is advisable to inspect this wire very thoroughly before paying out the costly current-meter on it, to avoid the chance of the messengers sticking fast on a loose strand of the wire and the current-meter not working. The purpose of these weights is to separate the successive observations of the repeating current-meter from one another. Moreover the inspection will give warning of any weak place in the wire. To test it a weight of 100 kg was veered out to a depth of 1700 m and then wound in again.

In „de Zeeën van Nederlandsch Oost-Indië” ¹⁾ Tydeman deals with the occurrence of a strong sill current, renewing the bottom layers in the next basins. His opinion is based on the fact that soft bottom sediments are absent in Lifamatola strait. The following statement is printed on page 115:

„Waarnemingen, waaruit de uitgebreidheid en de snelheid van dien stroom te bepalen zouden zijn, zijn tot dusverre niet verricht. Wel echter valt reeds te wijzen op waarnemingen, welke geheel met het bestaan van een sterken drempelstroom tusschen Molukken Passage en Banda-zee strooken. Bij de vier loodingen, welke op dien drempel door de Siboga-expeditie werden verricht (station 194 t/m 197), werd n.l. uit respectievelijk 1504, 1476, 2001 en 680 m door den grondvanger van het lood geen korrel grond bovengebracht. Bij het eerste drietal bestond, blijkens de telkens versche butsen en schrammen aan het lood, de bodem uit kalen, scherpen steengrond (rots?); bij de vierde looding ontbrak wel is waar dit kenmerk, maar tevens elk ander spoor van grond, zoodat ook op deze geringe diepte, welke overigens niet meer tot den drempelstroom kan behooren, de bodem naar alle waarschijnlijkheid kaalgeschuurd was.”

An attempt was made to secure data of this current near the sill over which the water flows from the Pacific to renew the water in the Ceram and Banda seas and the adjacent inland seas. For this purpose we payed out the repeating current-meter to a depth of 1700 m. Although at 6 a.m. echosoundings had given a depth of 1800 m, the instrument brought up a mass of tough clay. Apparently the instrument had been dragged along the sea floor by the yawing of the ship behind the anchor. At a further observation at 1500 m depth the instrument was lost when it was only 15 m below the surface of the sea. In the preceding measurements in 1700 m, where the instrument had come into contact with the bottom only the bucket with the messengers had been lost, but beyond that there were no traces of violence perceptible when cleaning the current-meter. It is therefore difficult to believe that the wire rope should have been injured then.

The case remains inexplicable, so the loss taught us only that the measurement of sill currents at such profound depths is a dangerous experiment. Fortunately we had another repeating current-meter on board, of which the bucket had been lost during the last observations. So a new bucket had first to be constructed before this instrument could be used.

Observations with the ordinary Ekman current-meter gave no results in two successive attempts; the messengers passed the lever which turns the instrument on and off, without any effect. If this was due to a steep incline in the wire, the current in the niveau in question must have been remarkably strong. In view of this possibility the construction of the instrument had been modified by Marx & Berndt. In 700, 1000 and 1200 m all went well, in 1400 m however, both the messengers were again

¹⁾ E. J. Brill, Leiden, p. 115.

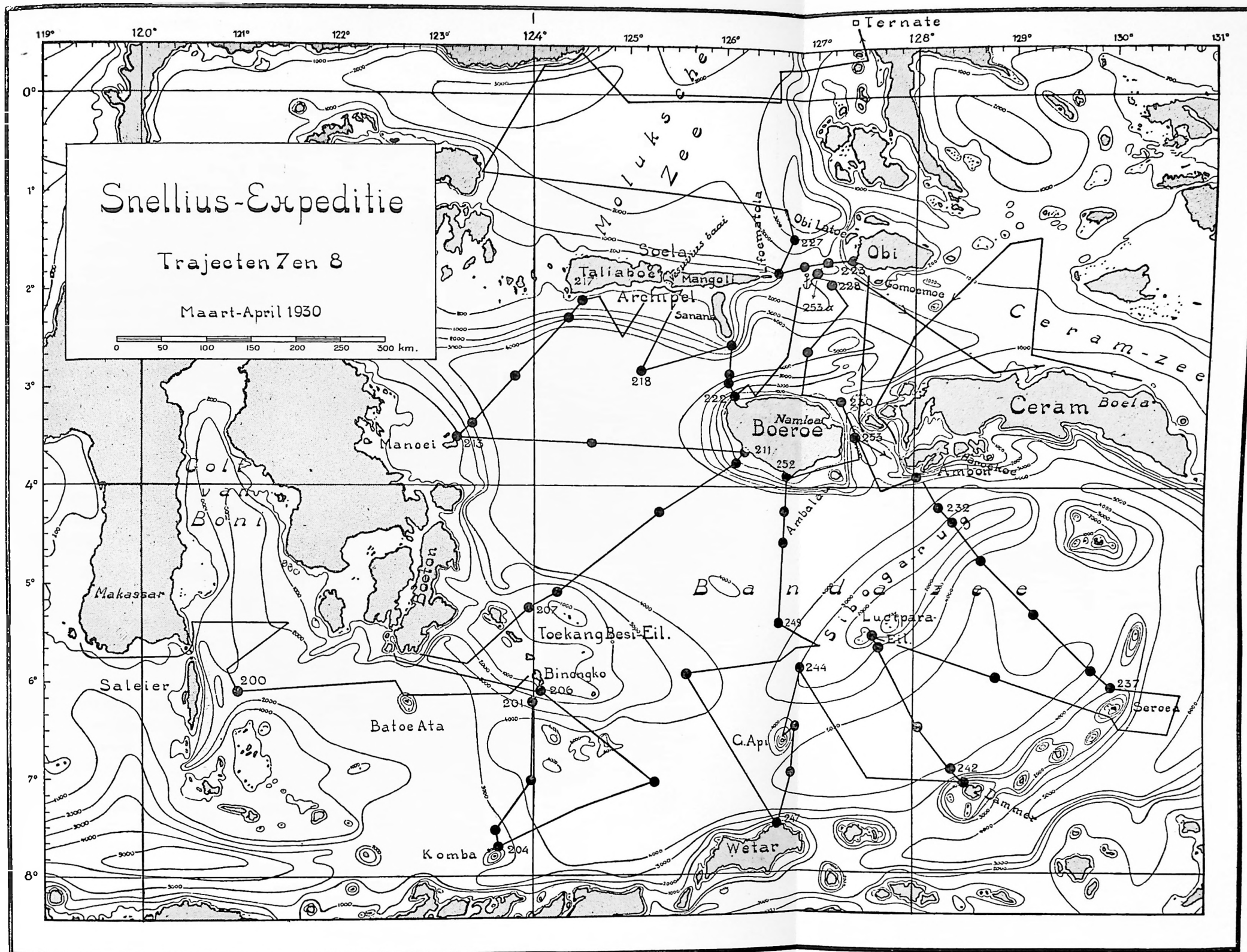


Fig. 11. Stations on the 7th and 8th track. Previous representation of the bottom configuration.



found at the top of the instrument, but only one of them hit the lever and did its work. Could this perhaps be due to a temperature or a pressure effect?

After an emergency bucket had been prepared for receiving the falling weights, the second repeating current-meter was used; all went well with this. The current-meters were taken to pieces afterwards and well cleaned with fresh water. The repeating current-meters are splendid instruments, every part of which is beautifully finished.

On the morning of April 27th the anchor was weighed, which occupied fully two hours. After the weighing of the anchor further observations were made from 900 m to the bottom to complete the serial observations. Six water samplers were hung upon the wire of 4 mm diameter and at the bottom a weight of 50 kg which was kept floating just above the sea floor while the dial of the dynamometer was constantly watched.

Weather conditions at the anchor-station were variable; whenever the wind and surface current were opposed the sea was rather rough. On 26th it was squally with showers of rain, maximum wind force 6. Visibility was poor so that no bearings from the shore could be obtained to verify the ship's position. The barogram showed some irregularities and the air pressure was below normal. The sea bottom was composed of good holding ground, tough well compressed globigerina ooze so that the anchor did not drag.

The landing-party returned on board before sunset, after which course was laid for Boela (N.E. coast of Ceram) to replenish the oil supply on April 29th. The following day we celebrated the birthday of H.R.H. Princess Juliana on board. A shadow was thrown upon the occasion by the serious illness of the Javanese stoker War. With all possible speed we made for Ambon, but to our regret the patient died before we arrived. He was buried on land next day, May 2nd.

This obliged us to give up the plan of depositing Kuenen on the island of Haroekoe and taking soundings in the Ceram sea. However, thanks to the friendly offices of the civil authorities at Ambon, Kuenen was able the same day to reach the island by car and perahoe, so as to carry out geological investigations for a few days.

d. NINTH TRACK, AMBON-TERNATE. MAY 8th—JUNE 3rd, STATIONS 253/—288.

During our stay at Ambon 12000 m of new piano wire was wound on the drum of the Lucas sounding machine, in preparation for the profound depths that were to be expected in the Pacific Ocean. In view of the fine weather that might be anticipated in this month our programme contained research in the portion of the Ocean bordering on the Archipelago as well as the entrance to the Molukken sea and the Sangihe trough.

On May 8th the „Snellius” left Ambon and we steamed to the native village of Palauw on the north coast of the island of Haroekoe, where we picked up Kuenen who had taken advantage of our stay at Ambon to pay a visit to the island. On the return journey the sounding machine was tried out at st. 253/ on the east coast of the island of Ambon. After this, echo-soundings were carried out on the rise of the sea bottom found to the south of the island and on the ridge which encloses the Manipa basin on the south side, to a depth of about 3000 m, detail chart 12. An oceanographic longitudinal section through Manipa strait was completed by observations at three stations; one in the Manipa basin, one to the south and one to the north of it; sts. 254, 255, 253, 256, 230 and 229.

At first at stations 254 and 255 there was some difficulty with the wire soundings because in veering out the Ekman tube the regular unwinding of the wire was hindered by the new piano wire on the drum relaxing. This defect, which was soon overcome, was probably due to the wire not yet being flexible enough and the paying out being done too rapidly.

On May 11th the observations in the neighbourhood of stations 228 and 253a were partially repeated to gain as many data as possible concerning the temperature and salinity of the depth water flowing through the strait. Here a weight of 50 kg was attached to the wire of 4 mm diameter. On this wire the serial winch paid out six Nansen water bottles so that the lowest one came to hang 50 m above the sea floor and the five others were each 250 m one above the other. By keeping a watch on the dynamometer the heavy weight could be held poised just above the bottom so that we could be sure that observations were actually being made 50 m above the floor *in the sill current*; sts. 258 and 259, detail chart 11.

On May 12th we anchored in the roads of Ternate where the help of the civil authorities was

called upon to enable Kuenen to pay a visit to the island of Morotai, to which a ready response was given by the Resident Mr. Hovenkamp. At Ternate two motor launches were left behind, with a view to the slight chance of bad weather in the Pacific, such as the Danish ship „Dana” had encountered in the previous year, south-east of the island of Mindanao. Between the main deck and the boat deck on the starboard and port sides of the officers mess-room a network of steel wire was made to break the force of the water when seas were shipped, plate XXIII. Although typhoons are very unusual in the area south of the parallel of 10° N. the dangerous zone occasionally extends to great distances on either side of their track. More than once we had seen that unfavourable weather conditions even far south in the Celebes sea coincided with storm centres passing over the Philippines and most probably were connected with these. But fortune favoured us, the Pacific Ocean did honour to its name. The barometer was above normal, the weather was beautiful and in the Ocean the surface was like a mill pond, without even a trace of swell. It was desirable, therefore, to steam north as rapidly as possible to make observations at the deepest spot upon the earth. But before submitting our sounding and serial machines to the highest test of their efficiency a preliminary wire sounding was made in about 8000 m at st. 260, using a Sigsbee lead which dropped a ballast weight of 40 kg when touching the bottom. Above the lead were fastened an ordinary Nansen water bottle and a reversing bottom water sampler. The former was reversed by a messenger attached to the bottom water sampler which was released when the latter reversed.

The sounding lasted $2\frac{1}{2}$ hours, that is, half an hour for the preparation, $\frac{3}{4}$ hour for paying out and $1\frac{1}{4}$ for hauling in. The Lucas machine worked well and stopped directly the lead reached the bottom. After this the serial machine was used with a steel wire rope of more than 8500 m length for serial observations at 4500, 5000, 6000, 7000 and 7500 m. All went smoothly, except that during the paying out the brake became slightly heated. The portion of the wire that had not yet been used was as good as new and lay tightly wound on the drum. The series occupied $3\frac{1}{2}$ hours: $1\frac{1}{4}$ h. paying out, $\frac{3}{4}$ hour for the reversing of the water bottles by means of the messengers and $1\frac{1}{2}$ h. for winding up.

When this was finished we visited the Emden Deep at about $9^{\circ}40'$ N. and $126^{\circ}50'$ E. where the German cruiser of that name had found an echo-depth of 10540 m¹⁾. According to the „Emden” this deep extended over 2×2 sea miles, so that finding the spot was no such simple matter, especially as there was a strong current running. Station 261, where a wire sounding in about 9800 m was made, proved, after fixing the ship's position to lie 5 sm south-east of the German soundings. Fig. 12.

At station 262, however, in about $3\frac{1}{2}$ hours²⁾ a sounding was carried out, by which a *bottom sample of red deep sea clay 54 cm long from a depth of 10068 m* as well as a water sample 30 m above the bottom with temperature was obtained. Accompanied by enthusiastic cheers the dial of the measuring wheel on the Lucas sounding machine for the first time passed the number 10000. The maximum echo-depth found at this station amounted to 10160 m. The thermometers had triumphantly born a pressure of more than 1000 kg/cm²; a word of commendation is here due to the constructors, messrs. Richter und Wiese, Berlin.

After the wire sounding, serial observations were carried out to a depth of 8500 m in accordance with the length of the 4 mm steel wire rope wound on the drum. The four series lasted about 13 hours, including the time needed for steaming northwards in between the series, as the ship was constantly carried southwards by the current. The ship's position was determined by fixes of stars in the twilight. After station 262 was completed the „Snellius” headed southwards, constantly taking soundings. More profound depths, however, were not found.

Between „Snellius” station 263 and the Palao Islands lies the „Planet” station 224. About 24 years previously this ship carried out serial temperature observations and salinity titrations on January 24th 1906, to a depth of 1000 m and bottom observations at a depth of 4500 m. The serial data of both stations correspond fairly well; the occurrence of the chlorine poor layer between 300 and 500 m depth was not so evident in 1906. The salinity and the temperature of the bottom layer observed by the „Planet” differ only slightly from those of the „Snellius” stations 262 and 272.

The observations at stations 263—267 provided the first oceanographic cross-section in the Min-

¹⁾ Probably 200 m less according to H. Maurer. Eine Nachprüfung der Emden-Tiefe. Ann. der Hydr. und Mar. Meteorologie. 1937, p. 108.

²⁾ In 1858 H.M.S. „Cachelot” had needed 12 hours to complete a sounding with a hempen rope at a depth of 4000 fathoms in the Banda sea.

passed. For the wire soundings the Sigsbee lead was generally used dropping the ballast weight of 40—50 kg when striking the bottom; this reduced to a minimum the danger of breaking the thin piano wire during the hauling in. At the last named station the dynamometer indicated while paying out, about 20 kg and at the hauling in of 9000 m wire, one Sigsbee bottom sampler and two water bottles, 80 kg. When the Lucas machine was stopped the strain on the wire (9000 m) was about 60 kg.

May 22nd we sailed to a point south-east of the island of Kakaroetan, detail chart 13, to begin the 2nd cross-section in the Mindanao trough, sts. 269, 270, 260, 271 and 272. Heading east, we found instead of increasing depths, first a deep narrow channel, which we named the Talaud trough, followed by a rise in the sea bottom 1900 m below sea level. This proved later to be a spur of the extensive submarine plateau which bars the principal entrance to the Archipelago. Near st. 260 where on May 13th we had previously made a wire sounding and series IV, the oceanographic observations were supplemented by the series I, II and III. At st. 272 the piano wire broke at a joint shortly after hauling in the sounding tube had begun, causing the loss of 5300 m of wire, with an Ekman sounding tube, a bottom water sampler, a Nansen water bottle and a reversing thermometer. This showed again, that with joints, however carefully looked after, there is always danger of losing valuable instruments.

About 55 years previously temperature observations to a depth of 4663 m were carried out by the „Challenger” at station 215, lying at a short distance from „Snellius” station 272. The results obtained at both stations differ only slightly; an error has, however, been made by the „Challenger” by assuming homothermal conditions from 2400 m downwards, temperature 1°.9 C., instead of a minimum of 1°.54 C. at about 3500 m depth, increasing to 1°.72 C. at about 5000 m. The salinities of the „Challenger”, calculated from the density observations are in general much higher than those of the „Snellius”.

At stations 273, 274, 275 and 276 successively observations were carried out. At the first two stations no wire soundings could be made, as the Lucas sounding machine had first to be provided with new wire. From st. 276 course was laid to the Kaoe bay. This bay, on the N.E. coast of Halmahera, has a maximum depth of about 500 m, while at the entrance to it the sill lies only 40 or 50 m below sea level. This depth is less than the amount of subsidence of the sea niveau during the pleistocene ice period. The principal object of our running into it was for geological investigation; we were to make an attempt with the heavy Ekman sampler to raise bottom samples of substantial length, in the hope of finding traces in them of fresh water sedimentation.

In succession observations were made outside the bay, on the sill and in the bay itself at sts. 277—280. The first sample that was raised within the sill exhaled an unpleasant odour like sulphuretted hydrogen. The oxygen titrations showed that below 400 m there was no oxygen present in the water, but there were traces of H_2S . Below the sill depth the water in the bay down to a depth of 500 m is almost isotherm, viz. fully 28° C., outside the sill at 500 m it is about 8° C. This place offers a fine example of inadequate renewal of the depth water due to the shallow entrance. The largest bottom sample, consisting of volcanic ooze, being 168 cm long, was raised at st. 278.

In the afternoon of May 27th we anchored on the east side of the bay, before the village of Akeselaka, where we rested next day.

On May 29th the ship left at 5 a.m. for the island of Morotai, where we anchored at 4.30 p.m. in the roads of Wajaboela; on the way we had carried out observations on the sill of the Kaoe bay at st. 281—282 without wire soundings. The following morning the ship left for st. 280 north-west of the small island of Doi. From here to the Talaud islands a cross-section was made in the entrance from the Pacific Ocean to the Molukken sea, sts. 283—286. When this was finished the necessary time could be devoted to the sounding of the area between the island of Morotai and the Talaud islands, detail chart 13. Here the greatest depth at which the water of the Pacific could enter the Molukken sea —2340 m — was adequately located. The results of the soundings induced us to carry out further oceanographic observations at sts. 287 and 288, to a depth of 700 and 2200 m respectively.

The weather remained favourable, calm, varied by slight to moderate southerly to S.W.-ly breezes; slight N.E.-ly swell. Fixing the ship's position by astronomical observations could not well be done. The ship was badly fouled below the water line, so that the speed was considerably reduced; this combined with a strong current insufficiently known deterred the accuracy of dead-reckoning. On June 2nd more soundings were taken to the west of the island of Halmahera, after which we anchored in the roads of Ternate on June 3rd.

During the eighth and ninth track the following physical-chemical determinations were carried out:

	t	S	O ₂	A	pH	P	H ₂ S	Wire soundings
Serial observations	1323	1359	984	105	1059	59	6	59
Surface observations	313	300				20		

Surface plankton was collected at nearly all stations. Horizontal plankton catches from the deeper layers with the large tow-net (straminpose) were carried out 13 times, dredging took place once. The wire soundings provided us with 15 bottom samples. For particulars concerning the investigations ashore, on the reefs and in shallow water I refer to Ch. IV of this volume.

When looking over the Lucas machine the diameter of the measuring wheel was taken, which showed that it was too small, giving the number of metres payed out too high. For particulars see Vol. II, Part 2, Ch. I, p. 6.

To prevent the occurrence of any unpleasant surprises in the Pacific Ocean in great depths while taking wire soundings, the piano wire was wound off the Lucas machine unto the drum of the serial winch standing one deck lower on the starboard side. After this it was re-wound and laid round the drum of the sounding machine at a constant tension, to a length of 12000 m with three joints at a distance of 1390, 5320 and 8271 m from the bottom sampler. In winding up and paying out the piano wire ran over the measuring wheel of both the Lucas machine and the serial winch. By a comparison of both readings it was seen again that the Lucas sounding machine registered 16 m per 1000 m too high. It is possible that the error was due to a fault in the construction and not wear of the instrument. On examining the measuring wheel of the serial winches it was seen that the registrations on starboard were correct; while on the port side they were 0.6% too high. At all events it was shown that it is desirable to examine the measuring wheels carefully before beginning work and to check them during the cruise.

Hamaker took great care constantly to change the combination of the thermometers when they were used in pairs. This showed up any constant errors which certain instruments might possess. With some instruments there was a good deal of trouble from after-flow of the mercury, with others the column of mercury did not break at the particular point in the capillary tube when the thermometer was reversed.

e. TENTH TRACK, TERNATE-SOERABAIA. JUNE 10th—JULY 12th, STATIONS 289—312.

After having spent Whitsuntide at Ternate, anchor was weighed on June 10th. The programme had to be so arranged that the ship could be back in Soerabaia before July 12th, while there must be an opportunity on the way, to take in oil fuel at Tarakan with the least possible loss of time. I therefore decided to conclude the research in the Sangihe trough, the Celebes sea and the entrances to it and to steam to Soerabaia through Makassar strait.

First Kuenen was fetched off at Wajaboela, a village on the W.-coast of the island of Morotai where, thanks to the much appreciated assistance of the Resident of Ternate, mr. Hovenkamp, he had received great help in his researches from the population, plate XXV. After this we crossed the Molukken sea to the straits between the islands of Siaoe and Tahoelandang (Sangihe group). In this narrow entrance to the Celebes sea the usual observations were made at st. 289, detail chart 3.

On June 12th, after making astronomical observations for fixing the position of a few islands, we sailed to the north and the following day we began observations along a cross-section in the Sangihe trough between the islands Beng Laoet and Northumberland, sts. 290—292, in supplement to the cross-section, st. 283—286.

After Boschma and Kuenen had been put off at Beo on the west coast of the island of Karakelong (Talaud islands) on June 4th, the sounding work was begun between this island and the island of Miangas, to determine the bottom formation and to decide upon the place for stations 293—295 on a cross-section of this, the most important, entrance to the Sangihe trough. The depth of the entrance was about 2000 m, detail chart 15.

The same method of work was pursued in the straits between Sarangani and the Kawio islands, which connects the Sangihe trough with the Celebes sea (Kawio strait). After we had procured sufficient data concerning the bottom formation in this entrance, we first made observations in the deep part of the Sangihe trough, st. 296, and on the inside of the sill in the Celebes sea, st. 297, after which the usual observations were made in the strait upon the sill, cross-section 298—300, detail chart 15.

The weather conditions were far from favourable, squally, rain showers, visibility poor and no moon at night. Wind south to south-west, force 4 to 5. During this time navigation demanded great care especially at night. In the straits there was a strong westerly current, with a velocity up to 3 knots. The carrying out of stations in the straits were accordingly not unattended by difficulties. At st. 299 in the centre of the passage observations were begun on June 19th at 4.30 a.m. when the depth was 1600 m. By the time the wire sounding and the first series were completed, the ship had drifted so far that the depth was only 500 to 600 m; these observations were made over again. In the serial observations it appeared that the thermometer-depths differed considerably from those deduced from the indications of the measuring wheel. As it was not impossible that the messenger had stuck on some obstacle or other so that the water samplers with their thermometers had not reversed at the right moment, the 2nd series was repeated. Again a great discrepancy was found between the depths acquired by readings of the measuring wheel and those corresponding to the readings of both protected and unprotected thermometers. The differences were about 100 m at a depth of 500 m, 200 m at 800 m and 300 to 400 m at 1200 m. With a strong surface current it is important to increase the weight at the bottom of the wire, to diminish the incline.

On June 20th we followed a sounding track to the N.W. point of the island of Karakelong, detail chart 15, and from there to the kampong Beo on the west coast of the island, plate XXIV. The following day, after Boschma and Kuenen had been taken on board again, at 10 p.m. the anchor was weighed and we steamed to the Celebes sea. In passing the Sangihe ridge, which connects Celebes with the island of Mindanao, a smallest depth of about 1200 m was found between the island of Sangihe and the Kawio Group. Owing to lack of time, we were unable to undertake the search for a shallow spot at 4° N. and 124°10' E. reported in 1922 (see depth chart I, found in Vol. II, Part 2, Ch. II).

From the island of Kamboling (Kawio Group) in the east to Tarakan in the west, the usual observations were carried out at sts. 301 to 306, so that a cross-section was obtained in supplement of sts. 297 and 299, at right angles to the one carried out in the previous year in the Celebes sea. Here the serial observations at stations 56 and 75 were repeated, to test the change in the properties of the sea water after a lapse of one year. The changes proved to be but slight.

During the cross-section the sky was often overcast, with occasional showers, so that we usually had to rely upon dead-reckoning for fixing the ship's position. There was only a slight breeze and the sea was smooth.

On June 26th oceanographic observations were made to a depth of 150 m at st. 306, the total depth being 1000 m. We confined ourselves to the 1st series, to test in how far the influence of the river water made itself felt upon the properties of the surface layer. In order to be in the roads of Lingkas (Tarakan) before dark, we abstained from carrying out observations in greater depths. During the previous night we had apparently been carried considerably to the south by the current.

On June 27th the fuel supply was replenished and we left Tarakan the same evening, to make observations in the night to a depth of 55 to 150 m at stations 307 and 308 in completion of the observations at st. 306. After this we steamed to a point to the south-west of st. 75, where we anchored on June 29th at a depth of about 4900 m, st. 308a, with 6500 m cable out. This manoeuvre took 4 hours.

The observations at the preceding stations had shown that the variations in the properties of the sea water which occur in the course of a moon's day, pointed to vertical displacements of water layers in the *same* direction. At st. 208a, therefore, we confined ourselves entirely to temperature variations, but extended the observations to nine niveaux. The position for this station was chosen so as to be able to investigate whether the variation in the properties of the sea water at a great distance from the coast in the extensive basin of the Celebes sea, were of the same importance as in the straits, where the movement of the tide is felt so much more strongly. The temperatures were determined 28 times successively, with an interval of about an hour, at 0, 50, 100, 150, 200, 250, 300, 400 and 600 m.

The thermometers were always payed out in pairs, so that for each observation two readings were available, while at the depths of 300 and 600 m, the pair consisted of a protected and an unprotected thermometer as check upon the depth at which the observations were being made.

With a view to the current observations, also, it was important not to carry out the original plan of anchoring on the sill in the principal entrance to the Celebes sea between the island of Mindanao and the Kawio islands. Here measurements would be strongly influenced by the displacement of the ship with relation to the anchor under the influence of tide currents. Moreover, owing to the bad holding-ground and the strong surface current there would be a great chance of the ship dragging, which would make the observations worthless.

On the programme for st. 308a the first place was taken by current measurements in 0, 50, 150 and 400 m so as to compare the vertical differences in current observed with those that were calculated. After this an effort would be made to determine the direction and velocity of the current at a depth of 4000 m. At first the repeating current-meter did not work properly and when this was put right, came the message that the serial winches, from which the current-meters were payed out, must not be used, on account of the rattling they made. They were, namely, installed close to the sick-berth in the forecabin, in which one of the native crew lay dangerously ill. After observations had been made for some hours with the electrical boat winch, they had to be stopped too, owing to the death of the patient.

In each of the above mentioned niveaus, however, in the course of some 11 hours a succession of observations had been obtained, while at 10, 25, 75, 100 and 250 m a few observations were carried out and the surface current was determined during 48 hours. A complete set of serial observations and the wire sounding, had unfortunately to be abandoned.

In the night of July 1st the anchor was weighed, which occupied fully 6 hours. According to the indications of the dynamometer during the hauling up of the anchor the tension in the anchor cable rose to 5500 kg. The weather since our leaving Tarakan had been far from agreeable, warm and dull S.W. wind with south-westerly swell, wind against current and consequently sea rather rough. At the anchor-station the weather at first was even worse, rain squalls from westerly directions, maximum wind force 7. In the evening of June 30th it began to improve. The astronomical observations showed that the ship had not dragged.

After anchor had been weighed we steamed at maximum speed to Tarakan and anchored there in the night of July 3rd in the roads of Lingkas. The following morning at 11 a.m. the mortal remains of the engine-man Sarbini were laid to earth with military honours. We left the roads the same day.

After leaving Tarakan, an ordinary wire sounding was made east of the island of Marathea at st. 309. This was accompanied by observations at 90, 60, and 30 m above the bottom, depth approx. 5000 m, with three ordinary water samplers above one another. Above these was a reversing thermometer frame, which on being hauled in, released the messenger after a few turns of the propeller causing the water samplers to reverse. The original plan, of carrying out this wire sounding with the heavy bottom sampler of 4 m could not be followed, owing to the sea disturbance.

The state of the weather had not improved and as the ship made little progress under the influence of current, wind and sea disturbance, the number of rotations of the machine were raised to enable us to carry out a few observations on the way to Soerabaia, sts. 309—312. At a few stations the observations of last year were repeated as the salinity results obtained then did not seem to us to be quite reliable. And indeed at some niveaus great deviations from previous observations were found in the salinity. Probably the titrations during the first month of the expedition occasionally yielded inaccurate results, owing to insufficient rinsing of the bottles into which the samples for testing were run off. After the completion of the observations at the last station, we were obliged to make for Makassar directly, in consideration of the condition of another patient, who fortunately could be taken into the hospital there in time. The 8th of July was passed at anchor, so as to be able to clean up the ship a little before our arrival at Soerabaia, and to inspect and clean our instruments. This time was also given to taking some films.

Various signs indicated that the health of those on board, after nearly a year of exacting work, had suffered somewhat and that it would be highly desirable to take a rest for a longer time than usual. The ship, which was badly fouled had to be taken into dock, and some repairs would be necessary. On

July 9th we left Makassar and steamed direct to Soerabaia, so as to arrive there upon the previously arranged date. The soundings on our programme were obliged to fall out, as well as the visit of Boschma and Kuenen to the islands south of Makassar in the Java sea. During the passage there was a strong east monsoon.

On July 11th we anchored in the roads of Soerabaia and moored the following day in the Naval Docks.

On the tenth track the following physical-chemical determinations and wire soundings were carried out:

	t	S	O ₂	A	pH	P	Wire soundings
Serial observations	664	404	313	44	374	27	17
Surface observations . . .	170	167					

Moreover 15 bottom samples were collected. Surface plankton was obtained at nearly all stations, horizontal plankton catches from the deeper layers with the large tow-net (straminpose) were carried out 5 times.

E. THIRD CRUISE

a. ELEVENTH TRACK, SOERABAIA-AMBON. AUG. 13th—SEPT. 10th, STATIONS 312a—330.

The duration of our stay at Soerabaia was originally arranged in consultation with the Commander to be a fortnight. But considering the state of health of those on board, the Naval Authorities considered it advisable to extend this term so that every one of the Netherlands crew might have an opportunity for passing a sufficient time in cooler surroundings and gather new strength to bring the research to a successful termination.

In arranging our plan of campaign, a long stay at Soerabaia had not been taken into consideration. As the ship had not been put at our disposal for research after October 27th I sent a request to the Vice-Admiral at Batavia asking to have the term extended for at most one month. I gratefully acknowledge that this request was immediately granted and that the Snellius Committee in Holland consented to the increased expenses, that this extension of the period would entail.

During the stay at Soerabaia all the instruments were thoroughly overhauled and kept in order. All the water samplers were taken to pieces, cocks etc. inspected, and well lubricated. The serial winches were painted, which needs to be done very carefully to prevent any damage to the smooth running of the apparatus. Any excess of paint that there might be was easily removed after our departure. They did not, however, get as far as taking the winches to pieces and thoroughly inspecting them. This was only done to the measuring wheels.

No meteorological observations were made at Soerabaia, the instruments were packed away, like the thermometers. The latter were tested by Hamaker at Pasoeroean between Aug. 5th to 12th. The testing ran satisfactorily. The errors that some thermometers showed, he repaired, according to the instructions given by the constructors, Richter & Wiese. Two new unprotected thermometers were received from Holland, suitable for readings from 0°—60° C. This supplementation was very welcome, as the supply had considerably diminished.

Refreshed after the fatigues of the last months we put to sea once more on Aug. 13th, with the exception of Boschma, whose work unfortunately obliged him to return to Holland. The collection of biological surface material was continued in the meantime by his assistant, the mantri Erie, under direction of the medical officer, Broekhoff.

The programme of the 11th track included current measurements in the Java sea and in the eastern entrance to the Flores basin, carrying out oceanographic observations in the northern part of the Banda sea, and as fuel was to be taken in at Boela, (N.E. coast of the island of Ceram) supplementary observations in the Ceram and Boeroe seas.

Aug. 13th we steamed out through the Western Entrance and anchored at night in the Java sea,

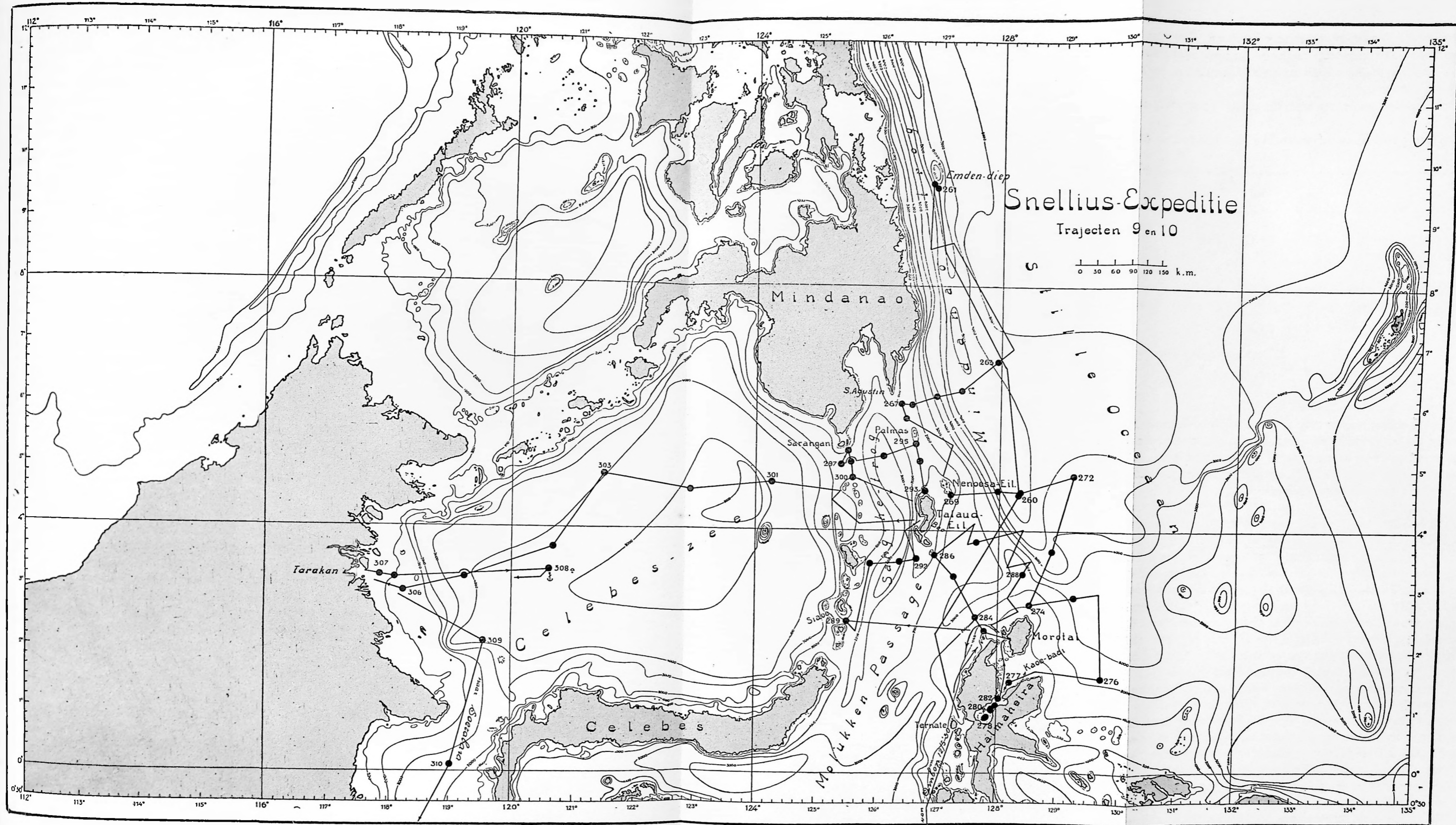


Fig. 13. Stations on the 9th and 10th track. Previous representation of the bottom configuration.

in about 60 m depth at st. 312a. Next morning at 6.30 current observations were commenced in niveaus 0, 10, 20, 30 and 40 m depth. We used the current-meter for strong currents by Ekman-Merz. The east monsoon was blowing strong and was accompanied by a certain amount of swell. The ship yawed considerably, which had a good deal of influence upon the accuracy of the observations. When the compass box was opened the shots were seen to lie all scattered, so that neither direction nor velocity could be accurately determined. The successive observations showed only slight variations; the general direction of the current was west, as might be expected during the east monsoon.

One of the Javanese crew developing an attack of appendicitis we were obliged to stop our measurements in the afternoon in order to take him as quickly as possible to the hospital in Soerabaia.

In consideration of what we have said above, the results of the current measurements were only of small value. As, moreover, all our time was needed to work off our programme, further observations at anchor-station 312a were abandoned.

After putting the patient ashore in the night of Aug. 14th we laid our course through the Eastern Entrance for Madoera strait, to seek the area of our activities. While sailing to the north of the Lesser Soenda islands towards the east, supplementary soundings were made and at sts. 313 and 314, the oceanographic observations at sts. 174 and 181 to depths of 1000 and 1800 m were repeated in order to test in how far the properties of the sea water, in the deeper layers, differ during west and east monsoon. In the east monsoon it proved that, at both stations, the temperature of the water near the surface was lower, while the salinity was higher than in the west monsoon. This seems natural, as the less chlorine water from the Java sea is carried eastwards by the west monsoon. On the other hand the fresh east monsoon carries the much cooler surface water of higher salinity towards the west.

At station 313 (east monsoon) the temperature at 50 to 200 m was, on the contrary, higher; this was also the case at st. 314 at 50 to 125 m. The difference was fairly important in 100 m viz. $\pm 4^{\circ}$ C. In these sub-surface layers, on the other hand, at both stations it was accompanied by a *low salinity*. Below 200 m depth, the differences at the two stations were divergent, and only slight. Station 313 lies in the strait between the Paternoster Group and the island of Soembawa, st. 314 is situated more easterly in the southern part of the Flores basin.

The east monsoon was at first moderate to strong with moderate swell, the further east we travelled the more the sea disturbance subsided and we could maintain our normal speed. Aug. 18th we anchored in the roads of Rioeng, north coast of Flores, to have a holiday next day and provide Kuenen with the opportunity for examining the ground in the neighbourhood.

After leaving Rioeng we steamed to the north, to the island of Kalaotoa, to carry out soundings in the area between it and Kakabia, detail chart 8. The properties of the sea water in the area south of the Gulf of Bone, namely, indicated an entrance of greater depth than found by echo-soundings (2180 m) between the islands of Kakabia and Batoeata in the neighbourhood of st. 193. A deeper entrance was only possible to the south of Kakabia, and here indeed we did find a passage with a minimum depth of 3240 m. The configuration of the sea floor differed here therefore to an important degree from the previous depth chart. This again demonstrated what important indications the properties of the sea water in the abyssal layers can give concerning the depth of the deepest entrance.

An important item on our programme was formed by the current observations at anchor-station 317a situated upon the sill which encloses the Flores basin on the east, detail chart 8. For comparison of the *direct current measurements* with the *calculated* differences of current, oceanographic observations were carried out at four stations round about this anchor-station, sts. 315—318. Aug. 21st we began paying out the anchor at 5 p.m. and completed at 10 p.m., depth 2350 m, length of cable 3300 m.

Immediately after this the current observations were begun with the repeating current-meter at 25, 75, 125, 175, 300, 600, 1000, 1500 and 2000 m while surface current was observed for 51 hours.

The first day, when current measurements were made to a depth of 600 m operations went very smoothly. In the deep observations however there was again great trouble with jelly fish, which attached themselves to the wire. The messengers stuck upon them, so that various measurements were spoiled and messengers were lost. This happened also to a few messengers that had performed their task, but apparently did not reach the bucket that hung below the current-meter. The last piece of apparatus had been constructed on board after the two that we had were lost in Lifamatola strait

at anchor-station 253a. It is possible that the bucket may have hung too low, and that after hitting the current-meter the messengers fell outside it.

On the afternoon of Aug. 24th we had finished. When the mushroom anchor had been weighed and appeared above the sea surface it was filled with a large quantity of mud from the sea bottom, plate XXII. Conditions had been extremely favourable, a smooth sea, calm weather and a clear sky. The last circumstance, which seldom lasted so long a time was made use of to carry out a large number of observations of the sun's radiation at different heights of the sun, plate XXVIII. After the conclusion of the current measurements the repeating current-meter was entirely dismounted, washed with fresh water and cleaned. It is very important that this should be done with great care.

Observations regarding the variations in the properties of the sea water in different niveaux, were not made at this station. Another important item consisted of sounding in the area of the Toekangbesi islands, detail chart 9. Here on the preceding tracks many soundings had already been made, which were now supplemented, so that finally a good idea of the bottom configuration could be formed in this area, which is of great geological importance. Aug. 26th we anchored in the lagoon between the islands of Hoga and Kaledoepa, where the following day we rested, plate XXVI.

The thermometers functioned well in general; occasionally we had some trouble from after-flow of the mercury. The new unprotected thermometers were very efficient. There was a good deal of play in the mountings of the serial winches, the starboard's winch especially, which was the most used, made a great deal of noise. The meteorological registering instruments were under Hamakers constant care.

After leaving our anchorage more soundings were taken on Aug. 28th in the area of the Toekangbesi Archipelago, and before sunset we took bearings of the island of Roendoema, for fixing the ship's position. From here we steamed to the rise of the sea floor (Luymes ridge) which we had discovered earlier to the south of the island of Boeroe and had called after captain Luymes, the first instigator of the research. This divergence from the existing chart was further investigated, for the minimum depth we found 530 m. It was not considered advisable to continue this research during the night, so we laid our course southwards over the Siboga ridge which is given in Tydeman's chart as one elongated rise of the sea bottom. In passing over this ridge it proved to consist of at least two parts lying „en échelon”, and separated by a depression of more than 4000 m depth. In future, therefore, we shall have to speak of the „Siboga Ridges”.

On Aug. 30th the observations carried out in April 1930 at st. 235 were partially repeated, st. 319. Here it appeared that in the middle of the Banda sea the temperature during the east monsoon in the highest layers is lower, while the salinity on the other hand is higher than in April (change of the monsoon). Below 150 m the reverse was the case down to 500 m. In 1000 m the differences were very small (see also p. 131). The following day the usual observations were carried out to a depth of 2500 m at st. 320 to the south of the Banda Group on the Inner Banda Arc. After the conclusion of these, the „Snellius” steamed to Banda on Sunday Aug. 31st where we anchored shortly before sunset in the roads of Banda Neira, detail chart 16.

On this historical spot, where a few fine houses still bore testimony to its former prosperity, we witnessed next day, the way in which the population celebrated the fiftieth birthday of H.M. the Queen, with popular games, processions, athletic sports, and rowing competitions. In the last, which are apt at the conclusion to give rise to slight differences of opinion (careful arrangements have to be made to avoid serious trouble!) the boats called *bélang*s took part, plate XXV. These are large war *perahoe*'s from different *kampongs*, decorated with flags and manned by some thirty oarsmen, who can give a great speed to their vessel with their peddles. It was pleasant to see how the whole population participated in these races and how from the poorest native hovel the Netherlands tri-colour floated. In the evening a procession of school children with chinese lanterns made by themselves presented a most charming sight.

On Sept. 2nd. we returned to a spot in the neighbourhood of the last station 320 in order to define the southern boundary of the Banda plateau and afterwards to carry out oceanographic observations on a cross-section in the Weber Deep, sts. 320—323, between the inner and outer Banda Arc. Here observations were made to a depth of 6700 m at st. 321.

It was now time to replenish our store of fuel, which was to be done at Boela (north-east coast of Ceram). On the way there supplementary data were obtained on two parallel sounding tracks

concerning the bottom configuration of the Ceram sea. Moreover observations were made at st. 324 in the deep northern arm of the Aroe basin to collect sufficient data for an oceanographic longitudinal section.

The weather conditions before our arrival at Banda had been very favourable. After our departure, however, it appeared that the east monsoon had only taken a temporary leave. In the Ceram sea, especially, the swell coming across from the S.E. and the wind with a force of 5—7 made sailing rather unpleasant. To diminish the list of the ship caused by the strong wind one of the ballast tanks on the port side was filled during the last sounding track.

Sept. 6th we left Boela. Owing to the bad weather we abandoned our original plan of pursuing our research in the northern part of the Banda sea. We thought it would be more profitable to conclude the research in the Ceram sea, for which observations were made at st. 325 to construct a longitudinal section along the axis of the deepest part in this trough-shaped area. Following this came a cross-section from the north coast of the island of Ceram to the southern entrance of the Halmahera sea, sts. 326—329. By comparing the observations at the last named station with those made on Oct. 2nd 1929 at the contiguous station 84, an estimation of the variation in the properties of the sea water could be made.

Fixing the situation for the stations on the last cross-section gave rise to some difficulty, because of the irregularity of the bottom configuration, which was different to what had been expected. The supplementary observations at a fifth station between 228 and 229 were postponed to a following visit to this area.

Although the weather conditions that day were not particularly favourable, at st. 330 a wire sounding was carried out with the large Ekman tube, weight 140 kg, at a depth of about 4500 m which raised a bottom sample of decalcinated deep-sea ooze of 152 cm length.

In spite of the sea disturbance the moment at which the sampler struck the sea floor was very clearly indicated by the tension meter. The three water samplers with thermometers gave the following data at 90, 60 and 30 m above the bottom:

Depth	t	S	O ₂
4360 m	3°.095 C.	34.61 ‰	2.55 cc/L
4390 „	3°.105 „	34.61 „	2.54 „
4420 „	3°.11 „	34.61 „	2.55 „

The depth of 4390 m was deduced from the readings of both protected and unprotected thermometers.

The nearer we approached Manipa strait on the way to Ambon the less the sea disturbance became; we passed Kelang strait at night, detail chart 12, and reached the Banda sea again on Sept. 9th. The weather conditions here were better than might have been expected; the east monsoon had become milder, wind slight to moderate with a slight S.E.-ly swell. The last day of the track was devoted to soundings between Manipa strait and the Schildpad islands to be better able to determine the depth contours in this area, which appeared to consist of a succession of local rises and depressions. In the afternoon of the following day we anchored in the roads of Ambon.

While we were staying there Kuenen spent a few days on the opposite side of the bay on the northern part of the island in the district of Hitoë to collect geological data. This visit had been made known beforehand so that thanks to the help of the civil authorities, the population were of great assistance to him.

b. TWELFTH TRACK, AMBON-AMBON. SEPTEMBER 17th—OCTOBER 13th, STATIONS 331—361.

On September 17th after taking in water, we left the bay of Ambon. The programme for the twelfth track contained observations in the Molukken sea and the Halmahera sea, and after taking in fuel at Boela, on the return to Ambon observations south of the island of Ceram.

First, however, a few soundings were taken in the N.W.-ly portion of the Banda sea while more-

over in the centre of this area the observations at station 213 on March 15th '30 were partially repeated and the heavy sampler brought up a record sample at st. 331 of a length of 187 cm ¹⁾ from a depth of 5000 m. The sampler was payed out on the wire rope of 4 mm diameter. To this rope at 50, 300 and 550 m above the sampler ordinary Nansen water bottles with thermometers were attached, which were reversed by means of messengers, thus forming a combination of serial observations to 1000 m and a wire sounding. While hauling in the maximum tension according to the dynamometer was 775 kg. The heavy Ekman tube remained sticking in the ground for a long time, approx. 20 minutes, although the messenger was released on board before the sampler reached the bottom so that the ship should not remain too long in connection with the sea bottom. The three water bottles gave the following results for the bottom water layer in the N.W. Banda sea.

	Depth	t	S	O ₂
at st. 331 . .	4476 m	3°.18 C.	34.63 ‰	2.48 cc/L
	4726 „	3°.21 „	63 „	2.50 „
	4976 „	3°.25 „	62 „	2.50 „

When compared with the observations of st. 212 which were made at the same place in March, the temperature of the upper layers proved to be lower in September, while the salinity was higher. In the abyssal layers, the observations in 4500 to 5000 m in the two months were in agreement with one another with the exception of the oxygen contents at st. 212, which was about 0.10 cc/L lower.

After making more depth- determinations in the western part of the Ceram sea, the „Snellius” sailed to st. 80 in the Molukken sea, where on September 21st the observations of October 1st, 1929, were repeated, st 332. An interval of almost a year lay between the two series of observations, which had been carried out at the beginning of the change of the monsoon, so that a closer correspondence was to be expected than between stations 331 and 212. Yet the temperature in 1930 here too was lower at the surface down to 150 m and the salinity to about 100 m was higher than in 1929.

During the two following days observations were made upon a cross-section up to the coast of Celebes. This profile was temporarily abandoned after st. 334, to sound the area north of the Soela archipelago for a possible sub-marine connection between these islands and the central ridge in the Molukken sea.

This elevation proved to be severed from the plateau of the Soela islands by a deep channel. After concluding the supplementary soundings the usual observations were pursued on the cross-section to st. 339, after which st. 340 was carried out.

On Sept. 24th we anchored in Lembeh strait, N.E. point of the island of Celebes, towards sunset, when the beauty of the landscape was enhanced by the peak of the mountain Kalabat (2000 m) sharply outlined against the evening sky.

In the Molukken sea the south monsoon was blowing strong, especially on the west side near the coast of the island of Celebes, where the flying spray with wind force 6, reached even the boat deck. Here we also observed a strong current ($\pm 2\frac{1}{2}$ mile per hour) towards the N.E. which made the stations come to lie considerably more northerly than had been originally fixed.

When on Sept. 26th Lembeh strait had been left, the weather had not improved. In the strait N.E. of Celebes there was no shelter whatever and as the waves, especially where wind and tide were opposed, were pretty high, the plan of anchoring to make current observations was abandoned, and we began the second cross-section that day, st. 341—346. As we worked towards the east, the force of the wind and the sea disturbance rapidly decreased. After the second cross-section had been completed, observations were further made for a longitudinal section at st. 347 in the trough west of the island of Ternate. The heavy Ekman tube yielded a stratified bottom sample of 176 cm from a depth of 3000 m, volcanic ooze.

In the vicinity of station 347 lies „Challenger” station 197. The temperature observations carried out there 55 years earlier to a depth of 2194 m are in good correspondence with those of the „Snellius”.

Sept. 28th the „Snellius” moored by the landing stage of Ternate, where water was taken in next day and we had an opportunity of taking in fresh supplies. From here we steamed to the north

¹⁾ This record was beaten at st. 374 by a length of 206 cm.

coast of the island of Morotai, where on Oct. 1st the geologist was put off at the kampong of Sopie, to continue his researches of May and June, while the ship travelled to the north. The same day we began a nearer investigation of the depth of the sill between the Morotai basin and the Pacific Ocean, and made a few temperature determinations near the bottom, st. 348.

After Kuenen had returned on board on Oct. 2nd we set our course for st. 276, where the observations of May 26th 1930 were partially repeated, st. 349. Here, under highly favourable weather conditions, observations were begun in a longitudinal section from the Pacific into the Ceram sea.

Considering the limited time at our disposal we abandoned a more extensive research in the Halmahera basin. From the observations in the middle of the basin, st. 353, it appeared that the temperature, from a depth of 1000 m down to the bottom (2000 m) was constant and fairly high, viz. about $7^{\circ}.79$ C. It must be remembered that the deepest entrance to this inland sea is only 700 m.

Sunday Oct. 5th was spent at the anchorage north of the Boo islands. The great distance from the coast and the strong tidal currents did not prevent us from taking some exercise on shore. A few natives, who found a scanty shelter in temporary dwellings there, had fled in their perahoe's before our arrival.

After weighing anchor the following morning, in the straits west of the Boo islands observations were made at st. 354, after which we steamed to the place of anchor-station 354a. Here, after making a complete set of oceanographic observations, we anchored on Oct. 6th in 1350 m depth, before 1800 m of anchor wire rope, which was accomplished in $1\frac{1}{2}$ hours.

At 6 p.m. we began our current measurements at 0, 25, 50, 100, 150, 250, 400 and 600 m continuing for fully 30 hours, while besides this a few observations were made at 800 and 1000 m depth; the surface current was determined every hour in the usual way.

Measurements with the repeating current-meter ran very smoothly, although there was twice trouble with jelly fish on the wire. There was no more loss of messengers through their not falling into the bucket below the current-meter. After the measurements had been made the instrument was taken to pieces and carefully cleaned.

At 5.30 a.m. on Oct. 8th we began to weigh anchor, which went easily, so that at 7.15 we went under steam and were able to make oceanographic observations the same day at st. 355. This formed the last station of the longitudinal section: Pacific Ocean—Ceram sea, and also completed the cross-section between the north coast of the island of Ceram and the small island of Lawin, sts. 326—329.

Oct. 9th for the last time fuel was taken in at Boela; on the evening of the same day we again headed towards the south-east, to pass through the narrow Geser strait near the S.E. point of the island of Ceram on the following day and reach the Banda sea. Here, in the Weber deep, observations were made to 3000 m at st. 356.

Steaming on, in the direction of the island of Soeanggi, detail chart 16, in place of profound depths, 370 m was sounded. From further depth-determinations it proved that the depth contour for 1000 m stretched out further to the north from the Banda plateau than given in Tydeman's bathymetric chart. From the island of Soeanggi an oceanographic cross-section was made to the south coast of the island of Ceram on Oct. 11th and 12th, sts. 357—360.

At st. 358 the wire sounding yielded a sample of 138 cm, which showed about 20 distinct strata. During the last months the heavy Ekman tube had often been used to bring up long bottom samples from a depth of 4000 to 5000 m even when there was a troublesome sea disturbance. The mean length of these samples was, according to Kuenen, about three times as great as those raised by an ordinary Ekman sampler. The great advantage of procuring long samples is seen from the fact that in them stratification was repeatedly demonstrated. In the neighbourhood of volcanoes coarse sandy sediments are found, through which the ordinary Ekman sampler does not apparently penetrate and produces only a short unstratified sample.

After the conclusion of observations at st. 360, depth-determinations were carried out north of the Siboga ridges, to ascertain whether the northern ridge was connected with the plateau on which the islands of Ambon, Haroekoe and Saparoea stand. At the same time the spot was visited where H.M.S. „Cachelot” in 1858 had found radiolarian ooze; here at st. 361 the usual observations were carried out, whereby the wire sounding really yielded the expected result from a depth of 2600 m. On Oct. 13th we dropped anchor in the roads of Ambon.

Below follow a few remarks concerning the preliminary results arrived at during the 11th and

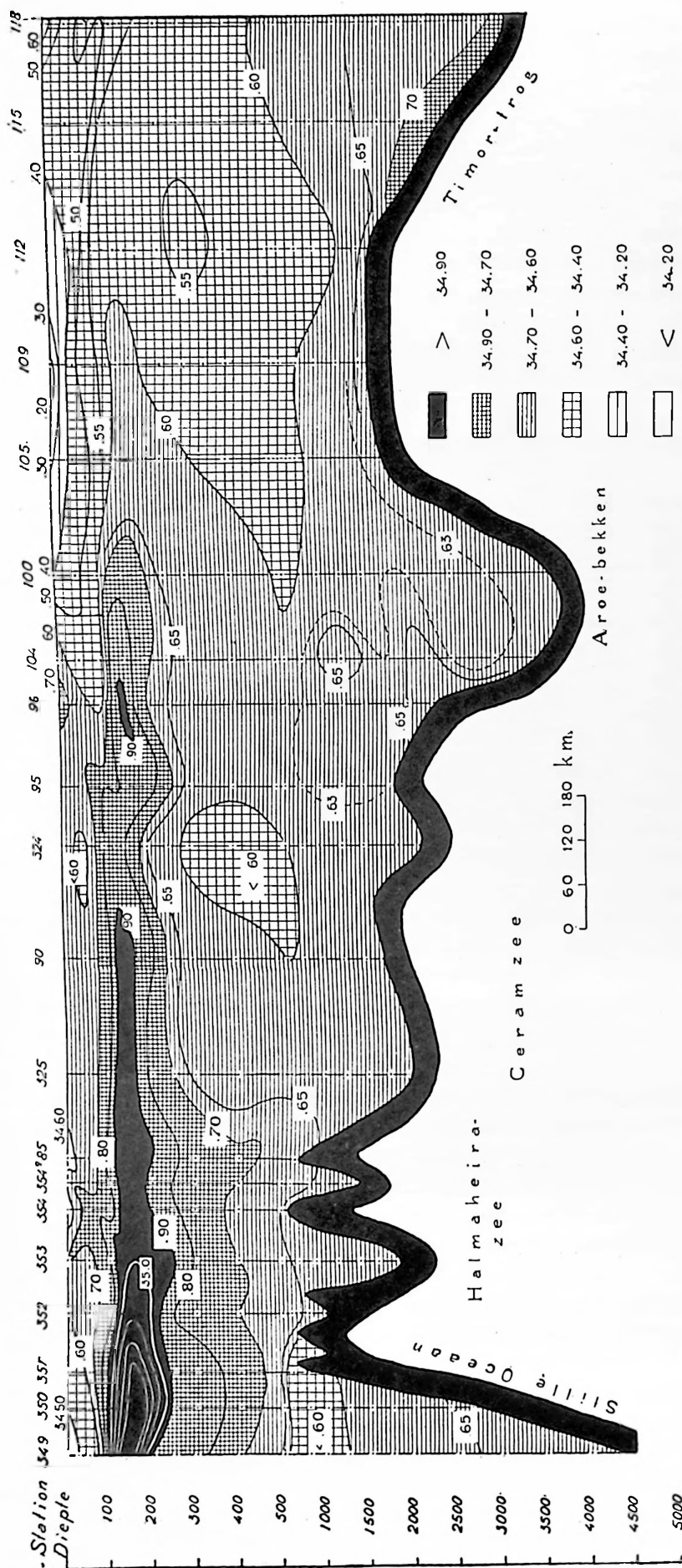


Fig. 14. Vertical distribution of the salinity of the sea water in a longitudinal section, showing the transport of water of high salinity from the Pacific Ocean through the Halmahera sea, the Ceram sea and the Aroe basin as far as the Tanimbar islands. (See also fig. 15).

12th track. The depth-determinations in the Banda sea gave a different representation of the bottom configuration to that of the former depth charts. By the severing of the Siboga ridge into two separate ridges and the addition of newly discovered rises, the conception of the inner Banda sea is disturbed and we are more inclined to divide the Banda sea into a northern and southern basin, while calling the eastern portion of the latter the Weber deep. These three parts are connected one with another to depths of more than 4000 m.

In the northern Banda basin the floor is fairly level, little accentuated depressions and rises alternate with one another, the former lying chiefly in the circumference of the basin, with depths of more than 5000 m. It will need a considerably greater amount of depth-determinations before the course of the rises can be accurately ascertained.

The southern basin, as regards its bottom configuration, greatly resembles the northern one. Here too we find shallow depressions the depths of which are only a little more than 5000 m and which extend between the island of Wetar and the Banda plateau in a direction W.S.W. —E.N.E. In the middle, isolated and surrounded by depths of more than 4000 m lies the plateau of the Goenoeng Api. Plate XXVI, fig. 10, p. 121.

Between the two basins appears a shallower irregular part of the sea floor which extends from the Toekangbesi islands to the island of Ceram. In this area the Lucipara and

the Schildpad islands rise above sea level. The Banda Group lies isolated upon a separate irregular plateau.

The Weber deep is on the east side near the ridge between the Aroe and Tanimbar groups very steep. The basin which shows no irregularities in its bottom configuration is the deepest of the inland seas, the most profound depth is over 7400 m.

On the north side of the fully 2000 m deep Halmahera sea lies a sill about 700 m below sea level. Here we did not find great differences with the existing depth chart; the soundings, however, were confined to the routes between one station and another. Here the layer of highly saline water flows from the Pacific through the northern entrance at about 150 m depth originating from the South Equatorial Current, the influence of which is felt in the Ceram sea, the Aroe basin and even as far as the Tanimbar islands, at a distance of 1200 km from the place of origin; figures 14 and 15.

In the transition area between the Halmahera and the Ceram seas, our observations allow a comparison between the properties of this layer in 1929 and 1930 *in the same season*. To eliminate to some extent the influence of the daily variation the mean at sts. 84 and 85 was compared with that at sts. 329, 354a and 355, which lie round about the first mentioned station. The higher salinity of the under current at 150 m in 1929 is distinctive. It is not surprising that in this flow from the Pacific Ocean variations from year to year should occur. The water transport is connected with the meteorological conditions, which are not identical every year either.

However important the water transport is from out the Pacific, through the Halmahera sea for the properties of the sea water *in the upper layers* of the easterly area of research, no renewal of the *abyssal layers* can be expected along this route. This is brought by water from the Pacific which after passing the Snellius-ridge and the Molukken sea, enters through the much deeper second access to the Ceram sea, the Lifamatola strait, between the island of Obi and the Soela Group. From here the bottom water finds its way to the Banda sea and the basins and troughs connected with it; figures 4 and 16.

In figure 16 a schematic representation has been given of the ridges, separating the sequence of inland seas between the Pacific and Indian Ocean with the potential temperature and the salinity belonging to the bottom water of these seas.

For the Pacific Ocean and the basins and troughs the depth has been estimated where the temperature equals that of the bottom water in the successive inland seas. Through these points arrows have been drawn.

During the flow of the water particles from the area of origin (Pacific Ocean) to the inland seas heat exchange occurs, consequently the arrows should not be interpreted as streamlines. The figure shows how the bottom layers are refreshed, even in the farthest basin (Sawoe basin), by water from various depths in the Pacific Ocean.

A second arm of the highly saline layer in depths from 100 to 200 m comes to the Archipelago through the entrance south of Mindanao, fig. 15. The consequence of this is that in the middle of the Celebes sea at 150 m depth, more than 35 grammes of salt were found per kg sea water. From the Celebes sea this highly saline layer stretches as a narrow tongue with more than 34.6‰ salinity southwards to close by Makassar.

The distribution of one of the most characteristic properties of sea water gives us an insight into the flow of the water in depths from 100 to 200 m. This is, however, not only the case with the distribution of salinity. The distribution of oxygen confirms the deductions made from the salinity that the flow of highly saline water to the Archipelago comes 1° through the straits south of Mindanao to the Celebes sea and Makassar strait, 2° through the Halmahera sea to the Ceram sea and further to more southerly areas.

With regard to the last mentioned transport we have at our disposal *direct* observations, viz. the current measurements at anchor-st. 354a, between the Halmahera and the Ceram sea. A preliminary working out of our results showed that the transport of water down to 400 m in general tends *towards the Ceram sea*. This confirms the deductions made from the chlorine distribution. The niveau of 100 m formed an exception; a resultant current in a northerly direction was found.

The mean velocity is not great. The maximum for surface current was 35 cm/sec while the mean resultant velocity in 50 and 100 m was only 15 cm/sec and in the deeper layers did not exceed 10 cm.

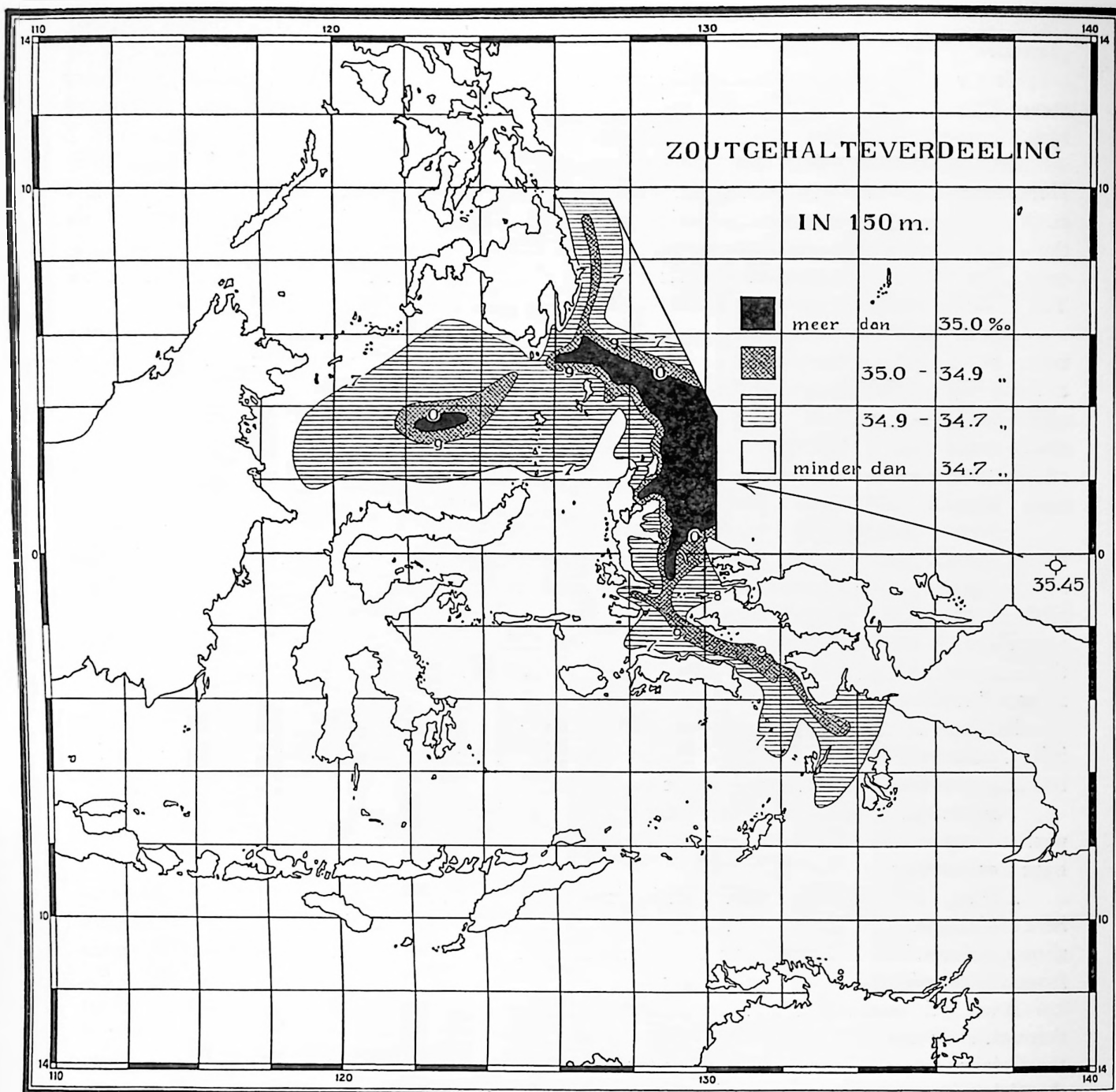


Fig. 15. Horizontal distribution of the salinity of the sea water at a depth of 150 m, showing the transport of water of high salinity by the South-Equatorial Current along the north coast of New Guinea towards the Archipelago. (See also fig. 14).

During the 11th and 12th track the following physical-chemical determinations and wire soundings were carried out:

	t	S	O ₂	A	pH	P	Wire soundings
Serial observations	861	837	658	114	797	74	38
Surface observations . . .	341	333					

Moreover 33 bottom samples were collected and surface plankton was obtained at nearly all stations.

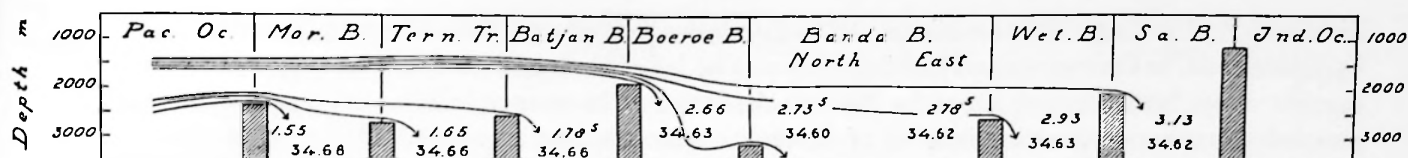


Fig. 16. Renewal of the bottom water either directly or indirectly from the Pacific Ocean.

c. THIRTEENTH AND LAST TRACK, AMBON-SOERABAIA. OCTOBER 20th—NOVEMBER 15th, STATIONS 362—382.

During our stay at Ambon, the diameters of the measuring wheels of serial winches and Lucas sounding machine were again tested.

The members of the expedition put the instruments in preparation for being transferred to the Royal Navy in the Indies, the Royal Magnetic and Meteorological Observatory at Batavia and of some laboratories at Batavia and Buitenzorg.

On Oct. 20th we took leave of the friendly inhabitants of Ambon and steamed for the last time through the beautiful bay out to sea. We owe many thanks to the then Chief Medical Officer of the Army, Dr. Bijlmer and his wife for their much appreciated hospitality.

Our programme contained observations in the Weber deep, Wetar strait and Ombai strait followed by a visit to the Sawoe sea, to collect more data at a few supplementary stations and to repeat some of our previous observations. Finally in the neighbouring part of the Indian Ocean a great number of depth-determinations were to be made and if possible observations regarding the properties of the sea water at great depth.

On the way to the Weber deep the Inner Banda Arc was twice passed, where a smallest depth of 1720 m was found on the northern Siboga ridge and 2300 m on the saddle between the volcanic islands of Manoek and Seroea. Weather conditions were favourable, slight S.E.-ly swell.

October 20th at 5 a.m. we began the observations at st. 362, the deepest station of the inland seas, 7300 m. By means of the serial winch depth observations were made in three series to 7000 m at 22 niveaus. For the wire sounding the Sigsbee lead (46 kg) was used, the weight of which was detached when striking the sea floor. This may have been the reason why the core tube did not penetrate sufficiently into the ground and a bottom sample of only 15 cm was raised. Above the Sigsbee tube 3 water bottles with thermometers were attached at a distance of approx. 30, 60 and 90 m respectively. Considering the great pressure in these profound depths it was not possible to add an unprotected thermometer to check the wire depth. The temperature was 3°.63 to 3°.63° near the bottom; the oxygen and salinity results also were very slightly divergent. The minimum temperature of 3°.08 C. we observed at 2700 m; from this niveau the temperature down to the bottom rose, therefore, 0°.55 C. owing to increasing pressure.

Station 362 lies quite near to station 193 of the „Challenger”. The temperature observations carried out here on September 28th, 1874, to a depth of 2800 fathoms (5121 m) correspond fairly well with those of the „Snellius”. The temperatures measured at 2743 and 5121 m were even equal to our results. As an increase of temperature in the abyssal layers was, however, considered impossible at that time, homothermal conditions were assumed from 1646 m down to the bottom. (Temperature 3°.3 C.). The salinity values derived from the density observations are, however, too high and the deviations from the „Snellius” results differ considerably.

To ascertain particulars concerning the water transport between the Weber deep and the Arafoera sea, more observations were carried out in supplement to st. 105, at sts. 363 and 364. At the conclusion of these the „Snellius” anchored on Oct. 23rd at station 364a at a depth of 4500 m and 5800 m anchor wire rope out, to take current observations and try again to get some comprehension of the velocity of the water movement at great depths.

Our original plan was to anchor at a depth of 3500 m. While the anchor was being payed out the ship drifted to the west, so that the depth on the steep eastern slope of the „deep” rapidly increased.

At the niveau of 3000 m seven series of continuous current measurements were made using the repeating current-meter, the most protracted of which lasted 1½ hours. Further measurements were made at 100 and 400 m depth, so as to compare the results with the currents calculated from the

distribution of pressure at these niveaux. The last series proved worthless after the instrument had been hauled in, as the messengers had been stopped by jelly fish that stuck to the wire, preventing the current-meter from working properly. Nevertheless the results were valuable, although we had not succeeded in procuring a complete set of observations during one moonsday. The current velocity at a depth of 3000 m varied from 2 to 12 cm/sec.

Although the anchor wire rope did not seem to be quite reliable in a few places, it fulfilled its duties to the last, which was in large measure due to the careful maintenance of it. The position of the ship was checked during the current measurements by astronomical observations and bearings of the island Moloe of the Tanimbar Group. The ship proved not to have drifted, weather conditions had indeed been extremely favourable. The officer on duty had attended to the ordinary observations of surface current, weather conditions, etc. (Vol. II, Part 3).

October 24th anchor was weighed, which occupied $5\frac{1}{2}$ hours, while at the same time a bottom sample was raised by the large Ekman tube, 160 kg. Above the sampler three ordinary water bottles were attached at 40, 900 and 1400 m distance, which were reversed by a messenger. In this way time was saved by combining a wire sounding with the serial observations of the third series.

After this sounding was completed the ship had drifted to the north west and at st. 364b complete serial observations were carried out of the 1st and 2nd series to depths of 2500 m. Stations 365 and 366 followed here, and more to the south st. 367 to complete the last cross-section in the Weber deep. As the observations at the stations 362 and 365 (7300 and 6300 m) had shown that the determinations for temperature, salinity and oxygen contents varied very little below 3000 m, at sts. 366 and 367 to save time observations were only made to 3000 m and the wire soundings were omitted.

Sunday Oct. 26th we headed for the area between the Tanimbar islands and the island of Babar and carried out the ordinary observations at st. 368, to get more data concerning the water exchange between the Weber deep and the Arafoera sea. After that we spent a quiet night in the anchorage north of the island of Seloe, detail chart 4. The following morning we left and continued the sounding work of the previous day to get a better idea of the bottom configuration between the islands, of Tanimbar and Babar. On the following night the last deep station 369 in the Weber deep was carried out down to the bottom, and on Oct. 28th the area north of the strait between the islands of Babar and Sermata was sounded. The oceanographic observations at station 370 formed a continuity with those south of the strait, sts. 113 and 114 in the Timor sea.

On Oct. 29th observations were made at the last st. 371 on the axis of the Weber deep in the extreme western part for the longitudinal section to 3500 m depth, the depth of the station being about 4500 m. Stations 372 and 373 gave us the desired data as to the connection between the Weber deep and the southern Banda sea.

In contrast to the Weber deep, north of the Sermata islands the sea floor proved to be very irregular so that much time was spent in sounding this area, as well as in carrying out the observations at the above stations and at stations 374 and 375.

At st. 374, depth about 2500 m, serial observations were carried out in two series to 1500 m preceded by a wire sounding with the large Ekman tube, weight 160 kg. On the wire at 50, 55, 250 and 750 m above the bottom of the tube ordinary Nansen water samplers with thermometers were attached, which were reversed in the usual way by messengers after the sampler had reached the bottom. *The bottom sample, globigerina ooze, attained the record length of 206 cm.* The readings of both protected and unprotected thermometers attached to the wire at 55 and 50 m above the sea bottom gave a depth of 2451 and 2462 m respectively. This serves to demonstrate the accuracy of the depth-determinations.

On Oct. 31st lying at anchor west of Leti, plate XXVII, we had a day of rest, and on Nov. 2nd Kuenen was able to collect geological data, when we stopped for 10 hours before the kampong of Wonreli on the west coast of the island of Kisar, but we did not anchor owing to the bad holding-ground.

The east monsoon was apparently still blowing steadily; only an occasional local shower pointed to the approaching change of season. The islands, like last year presented an arid and melancholy appearance. For the last two years it had been unusually dry here, so that at the islands of Leti and Kisar, for instance, there was a terrible scarcity of fresh water. On the latter island there was even

danger of famine so that the Government was obliged to send stores of food. Strangely enough, there was a great abundance of a small kind of mango, which was eaten in all sorts of forms. Apparently these mango trees demand very little from the soil upon which they grow.

After leaving Wonreli on Nov. 2nd complete observations were made for the longitudinal section on the axis of the Wetar strait at stations 376 and 377, after which on Nov. 3rd we made for a shallow of 25 m marked upon the sea charts and also found on Tydeman's depth chart. Our depth-determinations gave no indications of the existence of this shallow, neither was there any sign of discolouring in the sea water. It is however possible that we missed the exact spot and we had no time for a prolonged search.

After soundings to the north-east of the island of Kambing, detail chart 7, we steamed through the narrow Ombai strait and came again into familiar territory in the Sawoe sea. Here on Nov. 4th the observations made in Dec. 1929 at sts. 163 and 155 were partially repeated at sts. 378 and 379, after which another complete series of observations was made between the last station and the south coast of Flores at sts. 380 and 381, thus completing the cross-section 137, 154, 155, 379, 380 and 381.

Nov. 5th we anchored in the roads of Ende, where three days were devoted to cleaning up the ship and measures were taken for despatching the remainder of the inventory of the expedition, in so far it was still in good condition. Several of those on board took advantage of this opportunity for paying a visit to the celebrated coloured crater lakes.

High on the mountain peak, Geli Moetoe, a well built „pasangrahan" — a simple hotel for the use of Government officials when travelling — has been erected some years ago, from where these three mountain lakes, evidently filling extinct craters, may all be seen at the same time. This place may be reached from Ende by motorcar. Two of these are twin lakes separated from each other by a thin wall of rock, plate XXIX. The colouring, presumably due to mineral matter in suspension, is extraordinarily beautiful; one is yellow-green, the other of a deep red. The colour of the third lake, lying at a small distance, is under all weather conditions of deep blue.

Nov. 8th the „Snellius" left Ende, passed between the island of Sawoe and one lying west of it, detail chart 5, to the adjacent region of the Indian Ocean. Here a large number of depth-determinations were made, to ascertain in how far a connection exists between the deep depression (Soenda trough) which extends from here to 95° Long. E. to the south and west of the Soenda islands, Java and Sumatra, and the less deep trough in the western part of the Arafoera sea (Timor trough).

We borrow the following particulars concerning this from the preliminary geological report by Kuenen. The time given to extending the soundings in the Indian Ocean proves to have been very well spent. The results are more decisive than could have been expected. It is now beyond dispute that the elevation south of Java continues as far as Sawoe but the principal problem was to ascertain whether the Soenda trough extends as far as the Timor trough. The connection proves to be distinct. The Soenda trough in the transition area is from 1000 to 2000 m deeper than the area south of it. With the rise of the ocean floor towards the Australian shelf the bottom of the trough rises up also. South of Sawoe the depth is still 3500 m, at Roti on the outer sill of the Timor trough it is 2000 m, after this the depth in the last mentioned trough again increases.

Although the existence of a connection between these two components does not prove that they are identical, there must certainly, either in the mode of origin or in the geological construction, be a great resemblance. It is highly remarkable that the Timor-Ceram depression has something in common with a typical deep sea trench. It may well be regarded as the most important result of the soundings. So far we quote Kuenen.

The oceanographic observations were concluded by station 382 in the Indian Ocean, where for the last time the heavy Ekman sampler was used for the wire sounding. Up to the last, this instrument did good service, the length of the bottom sample was 178 cm, the maximum tension on the wire of 4 mm diameter was according to the dynamometer 650 kg.

During the last track the following physical-chemical determinations and wire soundings were carried out:

	t	S	O ₂	A	p _H	P	Wire soundings
Serial observations	393	389	329	63	379	25	19
Surface observations . . .	113	112					

Moreover 19 bottom samples were collected and at nearly all stations surface plankton was obtained. Concerning the investigations ashore and on the coral reefs we refer to chapter IV.

On Nov. 12th at 2.10 p.m. the last echo-sounding gave us the depth near Tg. Mamba on the south coast of the island of Soemba. This terminated the research and the ship returned to Soerabaia, where on Nov. 15th we anchored in the roads.

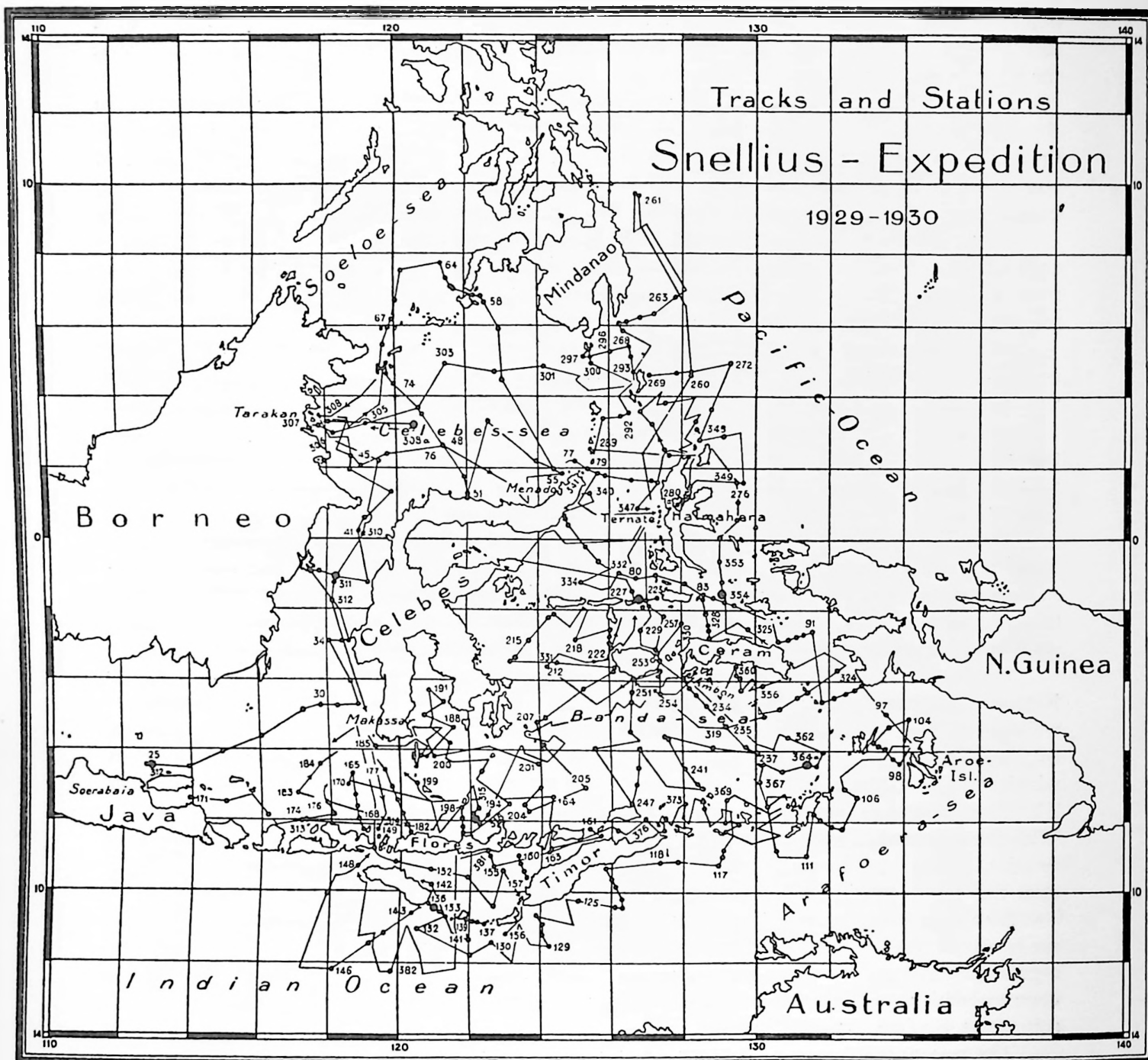


Fig. 17. All stations and tracks.

F. SUMMARY OF OBSERVATIONS AND FINAL REMARKS

During the period between July 27th 1929 and November 15th 1930 a distance of almost 34.000 sea miles was covered. Over this area the marine personnel carried out more than 32000 depth-determinations multiplying the number of soundings outside the depth contour of 200 m by 10. A great number of these were entered on separate fair sheets for drawing depth lines. Moreover a great number of bottom profiles were drawn. Based on this material a large depth chart, in two sheets,

and 16 detail charts have been drawn, referring to the eastern part of the Archipelago (Vol. II, Part 2, and Vol. V, part 2).

During the cruise the salinity and temperature of about 2000 water samples from the surface were determined; the latter was moreover continuously registered independently by a resistance thermometer fixed outside the hull of the ship. (Vol. II, Part 4).

While stationary, observations were made at 373 stations. Of these 353 were ordinary stations, eight were anchor-stations, at eleven stations *only* a bottom sample was obtained and at one station *only* biological observations were carried out. The temperature was measured at fully 7300 points between the surface and bottom; simultaneously about the same number of water samples were raised from the niveaux and examined on board. This research included fully 7100 salinity and almost 5300 oxygen determinations. The salinity was obtained from at least two chlorine titrations, the oxygen determinations were carried out in duplicate. The further chemical determinations consisted of alkalinity, over 700; hydrogen-ion-concentration about 5700; phosphates 200 and 6 H_2S -determinations.

At eight places we anchored at a maximum depth of something less than 5000 m to carry out current determinations at various depths and to collect data concerning the variations in the properties of the sea water at different niveaux (Vol. II, Part 3).

At almost every station plankton was obtained from the surface, while at the stations and also under steam several times with the vertical net or tow-net organisms were raised from the deeper layers. A few dredgings were made. On the coral reefs corals and also other biological specimens were collected, from shallow water and from the sea shore. (Vol. VI).

While stationary 349 wire soundings yielded about 300 bottom samples. The maximum length of the bottom samples amounted to 206 cm; the profoundest depth from which deep sea ooze was raised was fully *ten thousand metres*. The geological investigation was not confined to the configuration and properties of the sea bottom, but included that of coral reefs and little known islands. (Vol. V, Part 1).

Neither was the atmosphere neglected. The ordinary observations for the meteorological log taken by the Naval officers were supplemented by observations concerning rainfall, humidity and the sun's radiation. (Vol. III).

In preparing and settling the programme of research as much use as possible was made of the experience gained by former investigators, both by studying their reports and by personal or written consultations with colleagues.

At the same time, the circumstances of work are often so different, that, however earnest an attempt is made to arrange everything in detail beforehand, it is inevitable that during the research unforeseen difficulties will arise.

This applies especially to the instruments and methods of work. Hamaker in Vol. II, Part I will give some valuable information on this subject.

It was entirely due to the good mutual understanding, the interests of the expedition always being put first by every member of it, that the research could be carried out in 16 months, very nearly according to the pre-arranged programme. In settling this programme, I probably had not taken into proper consideration the effect of unbroken work during many successive days and nights in a tropical climate. On the third track, especially, great demands were made upon all on board, and after a year of observations, many showed signs of exhaustion. Only very occasionally was there any difficulty in combining the geological and biological observations on shore and on the coral islands and reefs with the station observations in the various basins and troughs.

The ship, as surveying vessel, was highly suitable for the research, especially so because during its construction the special demands of the expeditionary work had been taken into consideration, thanks to the inestimable co-operation of the naval authorities.

At the same time considering the large number of staff and the great extent of the research a larger ship with some more speed would have been more convenient. In the laboratories especially we were hard pressed for space. A combined locality for calculating and draughting was much missed. Such a locality brings people into greater contact automatically, and those occupied will sooner discuss and compare their preliminary results than when every one has to work separately in his own cabin.

In a larger ship the mounting of heavy apparatus and building of extra accommodation and laboratories on the upper deck, would not need to be compensated by arrangements to increase the stability of the ship, which our case necessitated.

At the conclusion of the research we returned home with extensive observation material. The working out of this will still need several years, particularly in the case of the physical-chemical oceanographic results, as most of the members of the expedition who had this work in hand found other posts immediately or sometime after the conclusion of the expedition, lying outside the scope of oceanographic science.

G. THE SHIP'S POSITION

a. ORDINARY STATIONS AND MEAN POSITION AT THE ANCHOR-STATIONS.

Underneath follows the list of stations. An *a* is added to the station numbers there and those on the chart when it was an anchor-station, an *l* when only a wire sounding was made and a *z* when only biological observations were carried out. One station is marked with a *b* when the ship had drifted too far after the anchor was weighed and a second determination of the ship's position had to be made (364 *b*). Column 3 and 7 give approximately the moment at which the wire was hauled up if it was a sounding, or when the uppermost water sampler of the various series was reversed. The last but one column gives the commencement and the termination of the station, the last one the depth in metres if a wire sounding was carried out; the position of the ship was determined by astronomical observations, bearings of conspicuous points ashore, or by dead-reckoning. Where two places are given, these belong to the beginning and the end of an ordinary station. For anchor-stations only the mean position is given.

Year Date		Station Nr.	Time					Position			
			Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
				I	II	III	Ia				
1929.								S.	E.		
July	27	25	17.30	18.19	—	—	—	6—22.5	112—48.5	17.15 18.30	61
	28	26	4.25	5.02	—	—	—	6—28.0	113—57.0	4.10 5.15	81
	28	27	15.15	16.00	—	—	—	6—01.0	114—57.0	15.05 16.15	61
	29	28	2.25	3.01	—	—	—	5—34.0	116—00.0	2.05 3.10	70
	29	29	16.55	17.45	—	—	—	4—55.0	117—18.0	16.35 18.00	683
	29/30	30	23.20	0.33	1.24	2.18	—	4—43.5	117—50.0	22.52 3.30	1771
	30	31	8.10	9.14	10.28	13.00	—	4—42.5 4—48.4	118—15.3 118—14.0	7.30 13.40	1882
Aug.	2	32	8.35	9.30	—	—	—	4—43.8 4—41.8	118—53.8 118—52.9	8.00 11.10	622
	2	33	18.00	18.02	19.55	21.05	—	4—02.4	118—40.0	17.30 22.15	1932
	3	34	14.53	15.55	16.35	—	—	2—52.2 2—56.0	118—22.0 118—22.0	14.17 17.05	1471
	3/4	35	19.05	21.05	22.07	23.35	—	2—51.3 2—53.7	118—29.7 118—31.1	18.30 0.53	2003
	5	35 l	9.00	—	—	—	—	2—39.6	118—53.7 ¹⁾	— 8.20	±20
	6	36	8.57	9.51	10.55	—	—	2—49.5 2—50.5	118—44.3 118—43.9	12.20 6.00	1116
	7	37	6.30	7.10	—	—	—	1—03.6	117—36.5	7.20 9.35	56
	7	38	12.00	10.11	10.55	—	—	1—04.3	117—56.8	13.05 16.15	1371
	7	39	16.45	17.58	18.48	19.55	—	1—12.7	118—20.5	21.00 3.15	2164
	8	40	3.40	4.26	5.10	—	—	1—21.4	119—11.6	5.30	1144
	8/11	39a	13.35	—	—	—	—	1—14.2	118—20.6 ²⁾	—	2164
								N.			
	12	41	3.00	4.05	4.56	6.00	—	0—10.4	118—56.7	2.30 6.40	2373
	12	42	16.48	17.40	—	—	—	0—28.1	119—06.9	16.36 17.50	690
	13	43	8.45	9.35	10.21	12.02	13.10	1—17.5 1—14.0	119—53.8 120—00.0	8.15 14.00	2079
	14	44	7.50	8.45	—	—	—	1—59.8	118—41.3	8.00 9.15	400
	18	45 l	10.14	—	—	—	—	2—10.5	118—40.1	8.14 11.30	1088

¹⁾ Anchorage Kg. Mamodjoe.
²⁾ Anchor-station, mean position.

Year Date	Station Nr.	Time						Position			
		Wire soun- ding	Serial observations					Lat.	Long.	Time	Depth
			I	II	III	Ia					
1929.								N.	E.		
Aug. 18	46	19.10	20.05	20.54	22.11	—		2—03.3	118—52.5	18.40	2088
								1—59.0	118—57.0	23.05	
	19	47	11.50	13.23	14.10	16.15	19.01	2—23.5	119—46.1	10.10	5132
								2—15.9	119—50.9	19.55	
	20	48	9.51	11.25	12.14	13.57	16.38	2—35.7	121—28.8	8.00	5515
										17.15	
	21	49	1.00	2.10	2.54	4.15	—	1—40.6	121—58.2	0.30	3010
								1—39.3	122—05.5	5.15	
	21	50	9.15	9.58	10.50	—	—	1—17.8	122—05.4	8.45	1713
								1—16.0	122—03.1	11.25	
	21	51	12.27	13.02	—	—	—	1—07.9	122—04.4	12.12	388
								1—07.8	122—04.8	13.15	
	23	52	11.45	13.10	14.00	15.15	18.53	3—17.1	122—35.4	11.00	5017
								3—18.5	122—31.8	19.20	
			Series IV:		17.05			2—12.5	123—59.0	7.40	
	24	53	8.17	9.53	10.40	11.50	15.28	2—10.6	124—05.2	15.30	5004
			Series IV:		13.40						
	24/25	54	21.10	23.23	0.07	1.25	2.50	1—46.5	124—34.0	20.35	3917
										3.15	
	25	55	4.44	5.22	6.00	—	—	1—38.9	124—39.0	4.20	983
										6.30	
Sept. 3/4	56	18.50	20.53	22.00	0.00	2.25		4—26.1	123—08.0	18.00	5009
								4—27.5	123—05.1	2.35	
	4	57	13.50	14.42	15.30	17.18	19.13	5—50.8	123—05.6	13.00	4651
								5—48.6	123—20.3	23.50	
	5	58	9.45	10.44	11.27	12.17	—	6—37.7	122—34.4	9.15	2722
								6—40.0	122—33.2	12.30	
	5	59	13.51	14.30	—	—	—	6—45.2	122—29.3	13.45	544
								6—45.7	122—30.2	14.50	
	5	60	17.50	18.10	—	—	—	6—47.6	122—16.7	17.40	90
										18.15	
	5	61	23.00	23.30	—	—	—	6—57.1	121—50.1	22.50	81
										23.30	
	6	62	1.05	2.15	—	—	—	7—02.0	121—40.0	1.05	452
										2.30	
	6	63	5.13	6.35	7.20	8.30	9.44	7—13.8	121—27.5	4.25	3067
								7—11.9	121—26.0	10.00	
	6	64	15.27	16.49	17.38	19.08	21.08	7—40.8	121—01.8	14.45	4299
								7—41.5	121—01.2	22.00	
	7	65	5.00	6.53	7.40	9.14	11.03	7—29.5	120—08.0	4.25	3981
										11.30	
	7/8	66	18.45	20.48	21.45	1.20	3.01	6—35.0	120—01.0	18.30	4483
								6—36.1	120—03.0	6.30	
	8	67	10.50	11.40	14.00	—	—	6—05.0	119—56.0	10.25	1975
								6—11.0	119—52.5	15.45	
	8	68	19.00	18.13	—	—	—	5—51.8	119—50.0	18.40	228
										19.20	

Year Date	Station Nr.	Time					Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1929.							N.	E.		
Sept. 8/9	69	23.55	0.45	—	—	—	5—19.5	119—44.5	23.45	334
							5—19.2	119—48.0	1.10	
9	70	8.15	8.39	—	—	—	4—49.9	119—30.6	8.05	125
							4—49.3	119—30.5	8.45	
9	71	10.45	11.22	—	—	—	4—51.9	119—40.3	10.40	263
							4—52.0	119—41.5	11.35	
9	72	12.35	13.08	—	—	—	4—52.8	119—47.1	12.23	198
									13.30	
17	73	18.45	19.32	20.23	—	—	4—40.8	119—41.7	18.00	1299
							4—40.7	119—42.0	20.50	
18	74	1.15	2.15	2.57	4.06	5.20	4—20.5	120—02.7	0.45	2637
							4—22.2	119—59.0	7.30	
18	75	17.07	18.27	19.22	21.05	23.15	3—29.5	120—46.5	16.30	4773
							3—28.2	120—43.0	21.30	
19	76	9.43	12.37	13.32	15.15	17.18	2—35.7	121—29.2	8.55	5544
							2—30.9	121—21.9	19.00	
21	77	15.40	16.45	17.52	—	19.00	2—09.7	124—59.5	15.10	2791
							2—09.3	124—58.0	19.10	
21/22	78	22.08	20.55	23.54	—	—	2—00.0	125—16.0	21.45	1499
							1—57.5	125—16.3	0.20	
22	79	4.15	5.37	6.40	—	7.55	1—50.4	125—41.3	3.45	2614
							1—53.4	125—40.9	10.00	
							S.	E.		
Oct. 1	80	6.00	7.19	8.30	10.05	11.49	1—07.5	126—44.0	2.00	4617
							1—05.8	126—49.3	12.00	
1	81	16.15	16.59	17.47	—	—	1—05.0	127—18.0	16.00	1666
							1—05.0	127—17.2	18.15	
2	82	2.08	2.56	3.37	—	—	1—14.7	128—10.9	1.45	989
							1—13.5	128—12.3	5.05	
2	83	9.33	10.07	—	—	—	1—38.3	128—24.5	9.20	378
							1—37.4	128—23.5	11.00	
2	84	14.55	15.43	16.26	—	17.14	1—40.5	128—47.0	14.35	1527
							1—40.5	128—48.7	17.35	
2	85	21.18	22.00	—	—	—	1—45.5	129—10.1	21.05	679
							1—45.5	129—08.9	22.20	
3	86	0.23	1.02	—	—	—	1—46.7	129—22.2	0.00	386
							1—46.7	129—20.8	1.10	
7	87	5.55	6.37	—	—	—	3—06.8	130—37.3	5.40	436
							3—06.5	130—38.3	6.50	
7	88	9.12	9.46	—	—	—	3—02.0	130—51.3	9.00	558
							3—01.8	130—52.4	10.10	
7	89	11.55	12.35	13.25	—	14.13	2—55.7	131—03.0	11.50	1415
							2—55.4	131—03.6	14.25	
7	90	16.25	17.09	17.53	—	18.45	2—50.2	131—14.0	16.00	1703
							2—49.8	131—14.8	20.40	
7	91	21.54	22.22	—	—	—	2—45.2	131—21.7	21.45	247
									22.35	

Year Date	Station Nr.	Time					Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1929.							S.	E.		
Oct. 8	92	15.35	16.11	—	—	—	4—37.5	131—46.0	14.35 16.50	682
8	93	19.58	20.41	21.23	—	—	4—30.8 4—31.2	132—05.4 132—05.2	19.40 21.40	1064
9	94	0.43	1.30	2.05	—	2.41	4—23.5 4—25.0	132—23.2 132—22.5	0.25 4.30	755
9	95	8.43	9.32	10.21	—	11.10	4—13.2 4—13.0	132—47.6 132—47.1	8.25 11.25	1825
9	96	12.30	13.08	13.43	—	14.20	4—08.5 4—09.0	132—51.5 132—51.7	12.20 14.40	854
9/10	97	21.18	22.15	23.10	—	0.10	4—48.5 4—49.8	133—25.5 133—28.1	21.00 1.50	2326
12	98	12.20	13.02	—	—	—	6—18.7	133—47.5	12.05 13.15	564
12	99	14.22	15.07	16.01	—	17.00	6—12.2 6—07.1	133—41.7 133—37.0	14.05 17.15	1848
12/13	100	22.48	0.15	0.59	2.05	3.27	5—51.9 5—54.9	133—21.0 133—21.8	19.55 3.40	3594
13	101	6.05	7.08	8.05	—	9.05	5—45.0 5—44.2	133—11.9 133—07.8	5.25 9.20	2139
13	102	10.32	11.34	—	—	—	5—38.9 5—38.6	133—02.3 133—02.0	10.19 11.45	372
13	103	16.00	16.30	—	—	—	5—19.4 5—16.0	133—32.0 133—35.9	15.30 16.45	671
13/14	104	20.30	21.50	22.34	23.45	1.02	5—01.5 5—03.7	134—00.0 134—00.0	20.00 1.07	3296
17	105	7.45	8.48	9.40	—	10.20	6—59.0 6—59.8	132—27.8 132—25.0	7.30 11.35	924
17	106	14.43	15.25	16.06	—	—	7—08.7 7—10.0	132—44.0 132—42.0	14.30 17.10	714
18	107	2.15	2.52	—	—	—	8—09.9	132—19.0	2.00 3.00	385
18	108	5.30	6.11	6.44	—	—	8—04.9	132—03.7	5.15 6.45	573
18	109	9.48	10.40	12.05	—	12.48	7—54.2	131—47.4	9.25 13.05	1504
18	110	15.13	15.50	—	—	—	7—45.9	131—34.6	15.00 16.05	233
19	111	0.14	1.03	—	—	—	8—44.8	131—27.7	0.00 1.25	557
19	112	10.20	11.10	11.55	—	12.50	8—39.7 8—38.4	130—36.0 130—34.3	10.00 14.45	1528
24	113	16.55	17.33	18.02	—	—	8—17.4 8—18.0	129—11.0 129—10.4	16.45 19.20	627
24/25	114	23.30	0.20	1.05	—	—	8—05.5 8—05.1	129—30.2 129—30.7	23.10 1.30	1437
25	115	10.20	11.08	11.58	—	13.05	8—51.6 8—51.0	129—01.3 129—01.2	10.00 14.45	2070

Year Date	Station Nr.	Wire soun- ding	Time				Position				
			Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1929.							S.	E.			
Oct.	25	116	17.15	18.03	18.53	—	19.51	9—02.8	129—01.0	16.35	1809
								9—02.8	129—00.5	20.00	
	25	117	22.40	23.17	—	—	—	9—21.0	128—59.0	22.25	553
								9—21.0	128—58.3	23.30	
	26	118	8.30	9.30	10.15	11.18	12.30	9—10.8	127—52.0	8.00	2843
								9—10.8	127—51.0	12.50	
	26	118z	Vertical plankton net					9—09.6	127—16.0	16.40	—
									18.15		
	27	119	4.55	5.40	—	—	—	9—11.0	125—53.3	4.35	604
									6.00		
	27	120	11.30	12.35	13.27	—	14.25	9—35.5	126—14.0	11.05	1981
								9—36.8	126—12.3	14.35	
	27	121	17.05	17.52	19.25	20.30	21.27	9—47.4	126—17.3	16.10	2254
								9—48.5	126—16.3	21.45	
	28	122	0.28	1.04	1.45	—	—	10—03.8	126—28.1	0.15	1159
								10—04.1	126—28.4	2.15	
	28	123	4.20	4.37	—	—	—	10—14.3	126—36.2	3.55	490
								10—14.8	126—36.6	5.00	
	28	124 l	12.57	—	—	—	—	10—27.0	126—31.0	12.50	364
									14.00		
	29	125	1.00	1.55	2.43	—	3.55	10—08.2	125—10.8	0.30	2609
								10—07.7	125—06.8	4.10	
	29	126	20.05	20.40	—	—	—	10—31.6	123—51.1	19.55	409
									20.50		
	29/30	127	23.38	0.31	1.25	—	2.28	10—47.9	124—00.8	23.15	2285
								10—51.1	123—57.3	4.55	
	30	128	7.18 9.30	8.00	8.41	—	—	11—01.5	124—05.3	7.00	1440
								11—01.5	124—10.0	10.00	
	30	129	13.45	14.17	—	—	—	11—22.0	124—18.0	13.35	425
								11—21.3	124—17.0	16.10	
Nov.	8/9	130	22.40	23.55	0.45	—	—	11—19.8	122—51.8	22.15	1826
								11—19.7	122—49.9	1.15	
	9	131	8.40	9.47	10.38	12.00	13.25	11—41.2	122—02.7	8.00	2901
								11—43.3	121—58.5	14.30	
	10	132	4.00	4.50	5.29	—	—	10—54.7	120—34.0	3.30	1303
										5.55	
	13	133	1.15	1.52	—	—	—	10—26.1	121—47.3	1.00	493
										2.10	
	13	134	5.00	6.00	6.45	—	—	10—20.1	121—31.4	4.30	939
								10—16.3	121—29.2	7.00	
	13	135	8.52	9.25	10.08	—	—	10—12.4	121—20.3	8.25	1155
								10—13.5	121—19.5	10.35	
	13	136	13.25	13.58	—	—	—	10—07.6	121—02.2	13.05	367
								10—06.2	121—01.7	14.05	
	16	137	13.20	14.00	—	—	—	10—46.3	122—29.4	13.10	440
								10—46.6	122—28.9	14.10	

Year Date	Station Nr.	Time					Position			
		Wire sounding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1929.							S.	E.		
Nov. 16	138	16.15	16.50	17.26	—	—	10—43.2	122—21.7	15.55 17.45	946
16	139	21.40	22.19	—	—	—	10—35.0 10—33.8	122—04.8 122—04.1	21.35 22.30	407
17	140	0.30	1.08	1.50	—	—	10—38.1 10—36.3	122—13.3 122—13.3	0.15 2.10	1071
17	141	6.35	7.34	8.18	—	—	10—59.4 11—00.9	122—04.7 122—04.7	6.10 9.40	1476
17/21	135a	—	—	—	—	—	10—07.4	121—17.7 ¹⁾	—	±1150
21	142	18.37	19.46	20.45	—	—	9—58.3 9—56.4	121—18.2 121—17.9	18.10 22.10	1821
23/24	143	23.30	0.22	1.05	—	—	10—28.4 10—29.7	120—19.1 120—20.0	23.05 1.30	1641
24	144	9.25	11.02	11.50	13.20	14.26	10—59.5 10—58.6	119—42.0 119—42.2	9.00 14.40	2769
24/25	145	20.00	21.58	22.45	0.17	2.55	IV 11—08.5 11—11.1	119—17.7 119—16.8	19.00 4.35	5722
25/26	146	18.20	19.30	20.18	21.50	23.51	12—02.9 12—05.1	118—09.8 118—06.7	17.30 0.10	5371
27	147	0.45	1.55	2.42	3.52	—	10—02.6 10—05.0	118—01.4 118—00.9	0.05 4.55	3675
27	148	18.00	18.26	19.03	—	—	9—08.9 9—09.6	119—01.2 119—03.0	17.30 19.30	1201
Dec. 7	149	5.30	6.25	7.07	—	—	8—12.0 8—11.5	119—24.5 119—25.0	5.05 7.45	1363
7	150	10.55	11.25	—	—	—	8—34.4 8—35.1	119—19.8 119—19.7	10.50 11.32	203
7	151	20.00	20.39	21.23	—	—	9—00.0 9—00.0	119—59.4 119—57.9	19.45 21.40	896
8	152	6.35	7.30	8.15	—	9.09	9—16.5 9—18.0	120—52.5 120—53.1	6.10 9.25	1918
8	153	18.30	19.41	20.40	21.42	—	9—40.5 9—43.0	121—52.7 121—53.2	18.00 22.30	2928
9	154	6.00	6.48	7.34	—	—	10—26.4 10—26.3	122—27.7 122—27.8	5.35 9.15	1976
9	155	17.30	18.22	19.03	20.12	21.30	9—29.5 9—31.4	122—43.5 122—41.8	17.00 21.45	3298
12	156	9.25	10.45	11.33	—	—	11—09.8 11—10.8	123—04.4 123—04.3	9.15 12.03	1856
13	157	5.25	6.10	—	—	—	9—35.5 9—35.7	123—39.0 123—38.0	5.15 6.30	438
13	158	7.50	8.40	9.23	—	—	9—28.8 9—27.5	123—34.5 123—34.8	7.30 10.00	1963
13	159	13.00	14.05	15.00	16.18	17.35	9—09.8 9—07.6	123—23.2 123—22.9	12.35 18.10	3250

¹⁾ Anchor-station, mean position.

Year Date	Station Nr.	Time					Position			
		Wire sounding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1929.							S.	E.		
Dec. 13/14	160	22.00	22.58	22.38	0.47	—	8—48.0 8—44.8	123—23.0 123—22.4	21.30 1.45	3221
16	161	10.45	11.32	12.03	—	—	8—18.3 8—18.1	125—20.3 125—19.6	10.30 12.20	979
16	162	14.15	15.07	15.53	—	—	8—25.2 8—25.2	125—30.2 125—30.0	13.55 16.25	2008
17	163	1.27	2.53	3.39	4.55	6.15	8—50.0 8—52.8	124—27.4 124—21.7	0.55 9.20	3296
17/18	164	22.17	23.42	0.20	1.30	2.56	7—27.6 7—26.8	124—25.0 124—30.0	21.40 3.05	3834
21	165	14.50	15.28	—	—	—	7—07.2	118—40.1	14.45 15.45	435
21	166	18.06	16.55	20.00	—	—	7—21.4 7—21.3	118—44.3 118—46.0	17.45 20.35	2002
22	167	1.07	2.20	3.03	5.02	6.17	7—49.5 7—49.5	118—54.3 118—56.4	0.35 6.35	3448
22	168	8.17	9.12	10.00	—	—	8—01.0 8—00.0	119—00.0 119—01.0	7.45 10.50	2559
22	169	12.05	12.40	—	—	—	8—06.9 8—06.9	119—03.5 119—04.0	11.55 12.50	576
23	170	6.00	6.30	7.08	—	—	7—26.0 7—27.0	118—45.9 118—46.8	5.17 7.35	1361
1930.										
Jan. 29	171	22.40	23.02	—	—	—	7—25.3	114—04.0	22.25 23.10	87
30	172	9.15	6.43	7.23	—	—	7—32.6 7—33.1	115—04.3 115—05.7	6.05 9.30	714
30	173	21.28	22.07	22.45	—	—	7—53.7 7—54.0	116—15.1 116—16.6	21.12 24.00	1511
31	174	9.08	9.48	10.35	—	—	7—59.5 7—57.8	117—19.4 117—20.9	8.46 11.00	1216
31	175	17.25	18.12	18.55	19.58	21.03	7—47.7 7—46.4	118—09.0 118—14.7	17.00 23.30	2656
Febr. 1	176	12.55	13.25	14.00	—	—	7—20.0 7—20.4	117—57.0 117—58.0	12.37 14.20	637
4/5	177	23.34	0.16	1.00	—	—	6—28.0 6—28.2	119—38.7 119—40.2	23.10 1.30	1533
5	178	5.55	6.48	7.30	8.30	—	7—02.1 7—02.7	119—50.6 119—52.8	5.32 9.15	2726
5	179	13.26	14.31	15.14	16.18	17.53	7—26.3 7—27.2	120—02.2 120—03.2	12.26 18.25	3947
5/6	180	21.35	23.16	0.00	1.40	3.57	7—47.1 7—47.1	120—06.9 120—10.8	20.50 4.15	5033
6	181	7.03	7.50	8.30	9.27	—	8—05.0 8—05.6	120—13.7 120—14.7	6.30 10.08	2832
6	182	13.12	13.46	14.15	—	—	8—14.6 8—14.6	120—16.4 120—17.3	13.00 14.35	890

Year Date	Station Nr.	Time					Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1930.							S.	E.		
Febr. 7	1821	8.00	—	—	—	—	7—40.8	118—20.1	7.55 8.00	79
10	183	15.30	16.03	—	—	—	7—08.0 7—07.5	117—08.0 117—10.5	15.20 16.20	503
11	184	7.08	7.45	—	—	—	6—23.4 6—23.0	118—12.8 118—13.3	7.00 8.00	357
13	185	12.20	13.55	—	—	—	5—49.2 5—52.7	119—22.2 119—22.1	11.50 14.15	620
14	186	5.27	6.06	6.48	—	—	6—16.8 6—16.8	120—33.5 120—34.3	4.40 7.14	1401
14	187	9.10	10.03	10.49	12.06	13.17	6—16.7 6—16.3	120—46.2 120—44.2	8.42 16.15	3098
15	188	1.37	2.09	2.43	—	—	5—23.0	121—38.0	1.20 3.10	1023
15	189	9.55 12.15	10.37	11.22	—	—	4—58.5 4—57.9	120—51.3 120—50.2	9.25 12.55	1862 1742
15	190	18.30	19.15	20.00	—	—	4—43.0 4—42.4	121—22.2 121—23.1	18.15 20.30	1407
16	191	1.05	1.44	2.43	—	—	4—19.0 4—18.1	121—01.6 121—03.0	0.35 3.20	1991
16	192	16.25	17.15	17.58	19.00	20.05	5—58.3 5—57.8	121—30.0 121—34.4	16.00 22.00	2552
17	193	20.50 21.25	22.20	23.10	—	—	6—33.9 6—33.7	122—26.6 122—27.7	20.30 23.40	1689 1648
18	194	10.35	11.26	12.11	13.14	14.40	7—39.0 7—35.4	123—01.9 123—08.6	10.00 15.00	2691
19	195	11.18	11.47	—	—	—	8—17.2 8—16.9	121—44.2 121—43.9	11.05 12.10	504
19	1951	12.30	—	—	—	—	8—16.5 8—16.9	121—44.0 121—43.9	12.20 12.45	1077
19	196	13.22	14.07	14.53	—	—	8—15.2 8—15.5	121—44.5 121—45.4	12.58 15.30	2216
19/20	197	18.58	20.13	21.05	22.45	0.24	8—00.3 8—00.9	121—37.6 121—42.8	18.17 3.00	5133
20	198	7.10	8.08	8.46	9.50	11.05	7—33.6 7—33.8	121—46.8 121—49.2	6.45 11.20	2804
23	199	13.35	14.20	14.54	—	—	6—49.0 6—49.8	120—26.5 120—27.0	13.15 15.13	790
March 5	200	18.25	19.00	19.35	—	—	6—05.7	120—59.8	18.07 20.00	1098
7	201	15.50	16.52	17.30	18.24	—	6—11.8	124—00.0	15.25 19.10	2969
8	202	2.10	3.23	4.11	5.27	6.57	7—00.6 7—01.0	123—58.0 123—59.6	1.15 7.10	3898
8	203	14.36	15.43	16.20	17.40	18.56	7—31.1 7—29.8	123—33.5 123—37.6	14.00 19.10	3500
8	204	21.05	21.40	22.20	—	—	7—42.0 7—42.0	123—37.0 123—38.4	20.45 22.55	1483

Year Date	Station Nr.	Wire soun- ding	Time				Position				
			Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1930.								S.	E.		
March 9	205	9.45	10.57	11.37	13.00	14.22	7—02.7	125—12.4	9.00	3936	
							7—02.0	125—14.8	14.35		
10	206	6.00	6.30	7.13	—	—	6—05.4	124—04.0	5.23	1217	
							6—04.0	124—03.2	7.40		
12	207	21.31	22.12	22.50	—	—	5—11.9	123—57.3	21.15	1186	
							5—13.2	123—56.6	23.20		
13	208	2.50	3.51	4.36	5.50	7.05	5—04.8	124—13.1	2.20	3556	
							5—05.3	124—14.1	7.29		
13/14	209	20.10	23.10	23.50	1.20	2.50	4—16.7	125—18.9	19.30	4225	
							4—15.7	125—16.9	3.05		
14	210	11.10	12.23	13.08	14.43	16.27	3—45.0	126—02.5	10.30	4907	
							3—44.2	126—10.0	17.05		
14	211	18.53	19.34	20.15	—	—	3—38.8	126—09.5	18.30	2025	
							3—38.5	126—09.5	20.59		
15	212	10.16	14.20	15.06	16.40	18.23	3—30.1	124—32.7	9.40	4917	
							3—35.7	124—32.7	23.15	4968	
16	213	10.44	11.21	11.54	—	—	3—30.2	123—11.2	10.26	1135	
							3—30.2	123—12.0	12.15		
16	214	14.02	14.51	15.54	17.00	18.05	3—20.2	123—20.2	13.35	3002	
							3—23.5	123—22.4	18.25		
16/17	215	0.10	1.20	2.03	3.20	4.58	2—52.5	123—48.6	23.35	4697	
							2—51.9	123—47.8	5.15		
17	216	11.48	12.43	13.21	14.26	15.38	2—16.3	124—19.0	11.30	3017	
							2—16.3	124—21.0	15.50		
17	217	18.35	19.15	19.55	—	—	2—07.1	124—27.5	18.07	1422	
							2—05.7	124—29.0	20.25		
20	218	15.55	17.04	17.48	19.12	20.45	2—48.4	125—07.2	15.17	4404	
							2—47.9	125—04.9	21.05		
21	219	20.25	20.57	21.30	—	—	2—32.6	126—03.2	20.05	1129	
							2—32.4	126—03.8	21.57		
22	220	0.40	1.25	2.15	—	—	2—48.9	126—00.8	0.15	2594	
							2—48.4	126—01.8	3.05		
22	221	5.00	5.55	6.36	7.47	9.14	2—56.4	126—00.4	4.15	3649	
							2—56.4	125—59.5	9.30		
22	222	13.10	13.45	14.23	—	—	3—03.7	126—03.6	12.50	1129	
							3—03.6	126—04.0	14.45		
23	223	20.50	21.22	—	—	—	1—39.7	127—21.0	20.40	486	
									21.45		
24	224	0.20	1.05	1.41	—	—	1—41.2	127—05.2	0.00	1085	
									2.10		
24	225	4.35	5.23	6.29	—	—	1—42.5	126—52.1	4.00	1911	
									7.14		
24	226	10.08	10.38	—	—	—	1—48.5	126—33.3	9.56	426	
									10.55		
24	227	14.53	15.31	16.25	—	17.35	1—27.4	126—44.6	14.15	2967	
									18.00		

Year Date	Station Nr.	Time						Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1930.								S.	E.		
April	4	228	20.30	21.22	22.14	—	—	1—54.3	127—08.3	20.00	2590
								1—54.8	127—07.5	23.05	
	5	229	5.45	7.02	8.03	9.45	11.45	2—33.3	126—56.8	4.50	
	5	230	21.04	21.44	22.25	—	—	2—33.8	126—55.1	12.10	5133
								3—06.9	127—16.1	20.40	1402
	6	231	10.19	10.53	11.34	—	—	3—08.3	127—14.0	22.50	
								3—52.8	128—01.3	9.52	1094
	7	232	12.30	13.45	14.30	16.03	17.48	3—52.9	128—02.3	12.00	
								4—11.2	128—15.9	11.50	4596
	7	233	20.10	21.00	21.43	—	—	4—12.1	128—17.0	18.10	
								4—21.2	128—24.0	19.54	1761
								4—22.1	128—23.8	22.20	
	8	234	2.35	3.38	5.26	6.45	8.07	4—43.0	128—42.0	2.00	3497
								4—45.0	128—41.6	8.25	
	8	235	15.10	16.30	17.25	19.18	21.10	5—17.0	129—14.8	14.30	5029
								5—20.1	129—15.8	21.55	
	9	236	4.10	5.25	6.10	7.22	8.40	5—52.0	129—49.0	3.30	3597
								5—52.8	129—49.5	8.55	
	9	237	14.15	15.11	16.08	—	—	6—01.3	130—03.1	13.50	3168
								6—03.5	130—02.4	17.15	
	11	238	—	1.15	1.58	—	—	5—57.4	128—51.2	0.45	—
								5—58.5	128—51.0	2.40	
	11	239	12.55	13.28	14.02	—	—	5—33.2	127—35.6	12.25	1236
								5—32.8	127—34.8	14.35	
	11	240	16.45	16.26	18.03	19.12	20.16	5—39.8	127—39.9	16.10	3130
								5—40.5	127—38.8	20.40	
	12	241	7.55	9.39	10.27	12.00	14.00	6—28.9	128—04.1	6.55	4829
								6—30.0	128—02.5	14.20	
	12/13	242	21.35	22.25	23.06	0.10	1.20	6—56.0	128—23.9	21.00	3341
										1.40	
	13	243	3.25	4.03	4.40	—	—	7—04.0	128—32.8	3.02	1129
								7—04.8	128—32.2	5.15	
	14	244	1.18	2.07	3.30	—	—	5—53.7	126—51.5	0.50	2565
								5—52.3	126—51.2	4.20	
	14/15	245	19.25	20.35	21.18	22.35	0.03	6—29.9	126—47.6	18.45	4423
								6—28.0	126—47.3	0.30	
	15	246	5.40	6.48	7.35	9.00	10.40	6—58.3	126—44.2	5.00	4364
								6—57.0	126—43.6	11.00	
	15	247	16.30	17.07	17.38	—	—	7—31.7	126—35.8	16.13	1519
								7—31.5	126—35.4	18.00	
	16	248	8.10	9.04	10.19	—	—	5—55.9	125—36.2	7.45	2645
								5—55.1	125—34.3	11.35	
	17	249	8.13	9.17	10.30	11.37	—	5—25.4	126—36.6	7.33	4091
								5—24.8	126—37.3	12.55	
	17	250	18.50	19.30	—	—	—	4—35.2	126—38.4	18.30	1027
										19.55	

Year Date	Station Nr.	Time					Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
			I	II	III	Ia				
1930.							S.	E.		
April 17/18	251	23.10	0.30	1.18	2.45	—	4—16.5	126—39.3	22.30 4.15	5078
18	252	7.20	7.59	8.35	—	—	3—54.2 3—54.3	126—41.3 126—41.7	6.50 9.15	1414
18	253	19.15	20.25	21.08	22.17	—	3—30.5 3—27.9	127—24.8 127—23.9	18.30 23.30	4024
23/27	253a	—	10.30	—	—	—	1—47.5	126—59.4 ¹⁾	—	±1800
May 8	253 l	17.14	—	—	—	—	3—42.0	128—19.7	—	931
9	254	—	5.27	6.11	7.23	8.45	4—20.9 4—20.9	127—24.2 127—22.8	3.00 9.10	—
9	255	19.35	20.45	21.20	22.17	23.28	3—47.3 3—46.5	127—22.0 127—22.4	18.45 23.50	3218
10	256	5.07	5.50	6.25	—	—	3—13.1 3—15.0	127—21.5 127—20.2	4.45 6.55	1197
10	257	17.40	18.27	19.11	20.12	21.20	2—10.5 2—09.0	127—32.2 127—33.0	17.05 21.40	2970
11	258	—	2.50	—	—	—	1—51.3	127—07.9	1.52 3.45	—
11	259	—	5.56	—	—	—	1—48.5	126—59.0	5.05 6.55	—
13/14	260	20.45	—	—	—	Ser. IV 23.15	N. 4—35.0	E. 128—18.0	19.40 1.45	7830
15	261 l	20.40	—	—	—	—	9—37.7 9—35.4	126—53.5 126—52.8	19.17 22.35	9877
15/16	262	—	—	7.08	5.15	Ser. IV 1.40	9—40.6 9—39.7	126—50.4 126—49.6	23.50 7.43	—
16	262	9.45	12.33	—	—	—	9—42.4 9—39.0	126—51.7 126—51.0	8.22 13.05	10068
17	263	18.45	20.20	21.00	22.15	—	6—47.5 6—45.0	127—56.0 127—56.1	18.05 23.25	3755
18	264	8.10	17.10	16.14	14.30	Ser. IV 11.05	6—19.5 6—15.8	127—19.8 127—21.0	6.55 17.30	9181
18/19	265	21.30	22.32	23.12	0.34	2.13	6—13.5 6—09.1	126—56.2 126—55.0	20.45 2.35	4886
19	266	6.10	7.13	9.19	—	—	6—03.5 6—00.9 6—04.1 6—01.7	126—32.0 126—31.0 126—33.6 126—32.2	5.35 7.44 ²⁾ 8.35 10.15	2382
19	267	11.35	12.05	—	—	—	6—03.0 6—01.5	126—22.0 126—20.7	11.23 12.20	417

¹⁾ Anchor-station, mean position.

²⁾ In consequence of strong current, head for the original position after wire sounding and first series.

Year Date		Station Nr.	Time					Position			
			Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
				I	II	III	Ia				
1930.								N.	E.		
May	19	268	17.30	17.58	—	—	—	5—50.5	126—27.0	17.15	782
								5—49.5	126—26.1	18.45	
	22	269	8.40	9.13	—	—	—	4—36.0	127—12.5	8.30	567
								4—35.8	127—10.9	9.50	
	22	270	16.25	17.40	18.20	19.45	21.15	4—37.7	127—55.4	15.40	4711
								4—41.5	128—01.4	21.50	
	23	271	1.25	3.45	4.30	5.25	—	4—36.3	128—18.9	0.10	7846
								4—39.0	128—21.6	6.50	
	23	272	13.50	14.37	15.28	17.05	—	4—54.6	129—07.1	13.00	5312
								4—54.8	129—17.4	18.40	
	24	273	—	13.10	14.00	—	—	3—39.3	128—52.1	12.45	—
								3—39.1	128—52.9	14.55	
	24/25	274	—	23.30	0.05	—	—	2—47.0	128—32.0	23.03	—
								2—46.5	128—31.9	0.25	
	25	275	13.25	8.20	9.00	10.30	12.22	2—51.7	129—14.4	7.45	5515
								2—54.2	129—12.3	14.30	
	26	276	—	8.00	8.40	9.55	11.28	1—34.4	129—41.7	5.55	4299
								1—33.7	129—42.5	12.05	
	27	277	0.55	1.32	—	—	—	1—30.5	128—12.5	0.35	567
									2.10		
	27	278	8.24 9.30	9.00	—	—	—	0—56.4	127—49.3	8.12	474
								0—55.8	127—48.7	10.05	491
	27	279 l	10.50	—	—	—	—	0—56.9	127—49.5	10.30	493
								0—57.7	127—50.2	11.05	
	27	280 l	12.30	—	—	—	—	1—05.1	127—55.4	12.20	201 1)
									12.40		
	27	280	13.30 14.20	13.57	—	—	—	1—03.2	127—54.3	13.20	369
								1—03.4	127—54.1	14.50	357
	29	281	—	6.35	—	—	—	1—08.8	127—59.1	6.30	—
									6.40		
	29	282	—	7.50	—	—	—	1—15.8	128—02.8	7.46	—
									8.00		
	30	283	11.40	12.04	—	—	—	2—21.3	127—46.0	11.20	569
								2—21.4	127—46.2	12.20	
	30	284	15.37	16.28	17.00	18.04	19.25	2—33.1	127—37.5	14.50	3684
								2—35.9	127—39.6	19.40	
	31	285	3.10	3.57	4.40	—	—	3—12.4	127—13.0	2.45	1949
								3—16.6	127—15.0	5.40	
	31	286	11.04	11.48	—	—	—	3—36.8	126—55.0	10.45	624
								3—36.1	126—56.2	12.00	
June	1	287	—	3.15	—	—	—	3—49.3	127—37.1	2.10	668
								3—49.8	127—38.2	3.30	
	1/2	288	—	23.50	0.33	—	—	3—17.0	128—23.1	22.35	2201
								3—17.2	128—23.4	1.15	
	12	289	17.15	17.57	18.36	—	—	2—30.2	125—30.8	16.50	1569
								2—30.7	125—32.0	19.15	

¹⁾ Table I, Vol. II, Part 2, Ch. I, St. 280 l, column 5 : 365 should be 203.

Year Date	Station Nr.	Wire soun- ding	Time				Position				
			Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1930.								N.	E.		
June	13	290	7.36	8.15	8.50	—	—	3—27.5	125—53.0	7.16	1143
								3—26.0	125—53.0	9.15	
	13	291	14.25	15.20	16.13	—	—	3—29.0	126—21.0	14.00	2517
								3—29.6	126—24.7	17.00	
	13	292	19.15	20.01	20.53	—	—	3—32.8	126—38.7	18.50	2443
								3—31.6	126—38.5	21.40	
	16	293	8.55	9.35	—	—	—	4—38.4	126—46.0	8.37	847
								4—37.9	126—46.7	9.55	
	16	294	15.47	16.28	17.04	—	—	5—07.2	126—40.5	15.20	1825
								5—07.2	126—39.9	17.45	
	16	295	21.55	22.41	—	—	—	5—25.6	126—36.0	21.40	920
								5—24.0	126—35.5	23.05	
	18	296	6.15	7.20	11.23 ¹⁾	9.06	10.12	5—16.0	126—05.8	5.38	3322
								5—10.8	126—03.0	10.30	
	18	297	18.45	19.34	21.00	—	—	5—05.3	125—23.9	18.20	2541
								5—04.8	125—23.1	21.55	
	19	298	2.45	3.15	—	—	—	5—19.6	125—33.7	2.15	806
								5—18.9	125—29.8	3.40	
	19	299	5.00	5.55	8.52	—	9.37	5—09.4	125—31.1 ²⁾	6.00	1495
					11.20	—	—	5—08.0	125—34.4	8.00	
								5—06.4	125—32.8	11.55	665
								4—51.4	125—35.0	14.10	
	19	300	14.24	15.00	—	—	—	4—53.0	125—32.5	15.25	5171
								4—48.0	124—16.7	23.30	
22/23	301	0.20	1.48	2.34	4.05	5.55		4—47.3	124—15.1	6.20	—
								4—39.1	122—56.9	16.00	
23	302	—	—	16.33	17.35	—		4—40.9	122—55.1	19.20	4419
								4—52.7	121—30.8	6.00	
24	303	6.50	8.08	8.46	10.00	11.42		4—53.8	121—29.1	12.20	—
										3.25	
25	304	—	3.52	4.29	5.20	—		3—41.5	120—41.8	6.20	3507
								3—13.8	119—03.0	20.30	
	25	305	21.00	22.05	—	—	—	3—12.7	118—57.5	23.45	—
										6.40	
	26	306	—	7.10	—	—	—	2—59.0	118—16.1	7.20	—
								3—12.9	117—52.6	9.35	
28	307	—	9.50	—	—	—		3—13.5	117—52.4	9.55	—
28	308	—	12.08	—	—	—		3—12.0	118—07.3	11.45	—
June 29/July 1	308a	—	—	—	—	—		3—21.4	120—36.3 ³⁾	—	±5000
July	4	309 l	14.45	—	—	—	—	2—10.0	119—32.0	12.30	5108
								2—10.8	119—35.8	16.45	
	5	310	—	11.25	12.07	—	—	0—07.3	119—02.0	10.53	—
										12.50	

¹⁾ Series II at 7.58 without succes; repeated at 11.23; ship's position 5—12.1 N., 126—03.0 E.
²⁾ Position wire-sounding and series Ia.
³⁾ Anchor-station, mean position.

Year Date		Station Nr.	Wire soun- ding	Time				Position			
				Serial observations				Lat.	Long.	Time	Depth
				I	II	III	Ia				
1930.								S.	E.		
July	6	311	—	2.58	3.40	—	—	1—11.6	118—18.9	2.25 4.20	—
	6	312	—	9.24	10.13	—	—	1—43.1	118—15.0	9.00 11.00	—
Aug.	14	312a	—	14.20	—	—	—	6—24.6	112—55.6 ¹⁾	—	±60
	16	313	—	19.55	20.28	—	—	8—00.0	117—17.9	19.30 21.00	—
	18	314	—	1.15	1.55	—	—	8—05.5	120—12.1	0.40 2.30	—
	21	315	—	4.58	5.40	—	6.36	7—36.7 7—36.0	122—19.2 122—19.1	4.30 7.00	—
	21	316	—	9.48	10.32	—	11.30	7—46.3 7—46.4	122—08.4 122—07.8	9.25 12.15	—
	21	317	—	15.55	16.42	—	17.53	8—00.3 8—00.9	122—18.5 122—19.5	15.20 18.05	—
	21/24	317a	—	—	—	—	—	7—55.0	122—12.7 ²⁾	—	±2500
	24	318	—	9.10	9.50	—	10.47	7—49.7 7—48.9	122—34.0 122—33.7	8.40 11.10	—
	30	319	—	21.25	—	—	—	5—17.6	129—14.5	20.45 21.50	—
	31	320	8.30	9.16	10.10	—	—	4—59.3 4—58.7	130—17.1 130—16.4	8.00 11.35	2564
Sept.	2/3	321	0.10	2.05	3.10	5.15	7.15	4—45.5 4—44.7	130—43.0 130—41.6	23.12 7.30	6625
	3	322	14.14	15.16	16.10	—	—	4—23.7 4—23.3	131—10.7 131—10.5	13.40 17.10	3314
	3	323	20.20	20.55	—	—	—	4—17.9 4—17.9	131—28.1 131—27.5	20.05 21.10	496
	4	324	7.53	8.35	9.10	—	—	3—42.3 3—43.2	132—16.1 132—14.4	7.25 9.55	2139
	6	325	18.05	18.48	19.30	—	—	2—28.8 2—28.0	129—50.2 129—49.7	17.40 20.05	1996
	7	326	6.40	7.08	—	—	—	2—47.0 2—47.3	128—48.6 128—48.7	6.25 7.25	474
	7	327	10.20	10.58	11.35	—	—	2—29.7 2—30.5	128—47.8 128—48.3	10.05 12.00	1445
	7	328	13.25	14.30	15.05	15.57	—	2—23.2 2—24.0	128—48.0 128—47.0	13.00 16.55	2942
	7	329	—	22.50	—	—	—	1—41.0	128—40.0	22.22 23.15	—
	8	330	9.57	9.03	12.00	13.10	—	2—23.0 2—22.0	128—01.6 127—59.6	8.35 14.25	4450

¹⁾ Anchor-station.

²⁾ Anchor-station, mean position.

Year Date	Station Nr.	Wire soun- ding	Time				Position				
			Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1930.							S.	E.			
Sept.	19	331	13.35	15.43	—	—	—	3—33.7	124—21.1	12.45	5026
								3—33.8	124—19.7	16.10	
	21	332	—	9.18	—	—	—	1—03.7	126—46.1	8.40	—
								1—02.9	126—45.1	10.05	
	21	333	13.25	14.12	15.03	—	—	0—53.0	126—22.0	12.55	2694
								0—51.7	126—21.2	15.50	
	22	334	4.30	5.19	6.03	—	—	1—09.6	125—18.6	3.55 6.50	2658
	22	335	17.40	18.33	19.17	—	—	0—33.0	125—45.5	17.15 20.00	2130
	23	336	1.07	1.55	2.45	—	—	0—09.7	125—22.0	0.35 3.30	2378
	23	337	9.30	10.40	11.20	12.35	14.00	N. 0—24.3	E. 124—52.1	8.55	3860
								0—26.9	124—54.6	14.20	
	23	338	16.25	17.08	17.45	—	—	0—36.8	124—49.0	16.00	1775
								0—37.8	124—49.8	18.20	
	23	339	20.00	20.20	—	—	—	0—45.4	124—43.3	19.45 20.46	398
	24	340	7.50	8.35	9.22	—	—	1—20.0	125—28.7	7.35	2510
								1—20.3	125—30.2	10.10	
	26	341	—	18.07	18.35	—	—	1—50.3	125—13.8	17.06	1305
								1—50.9	125—13.5	19.05	
	26/27	342	—	23.50	0.41	—	—	1—51.0	125—41.0	23.25	—
								1—51.2	125—41.4	1.30	
	27	343	4.30	5.07	5.40	—	—	1—48.6	125—58.6	4.15	1185
								1—49.0	125—59.5	6.05	
	27	344	11.50	12.40	13.35	—	—	1—42.5	126—39.0	11.25	2479
								1—43.1	126—40.6	14.20	
	27	345	19.03	19.50	20.37	—	—	1—41.2	127—14.0	18.38	2736
								1—41.6	127—14.2	21.20	
	27	346	23.05	23.40	—	—	—	1—37.8	127—24.8	22.52 23.55	492
	28	347	10.00	7.50	8.45	—	—	0—58.6	126—50.0	7.10 11.00	3061
Oct.	1	348 l	11.42	—	—	—	—	3—07.3	128—27.5	11.15 12.40	2198
	3	349	—	3.07	3.42	—	—	1—37.9	129—34.7	2.30 4.10	—
	3	350	9.50	10.37	11.20	—	—	1—05.1	129—37.1	9.25	2558
								1—06.2	129—36.0	12.00	
	3	351	16.05	16.40	—	—	—	0—39.7	129—37.6	15.50	788
								0—39.1	129—36.7	17.00	
	3/4	352	23.50	0.28	1.00	—	—	0—06.2	129—07.9	23.30	1018
								0—05.4	129—07.7	1.20	

Year Date		Station Nr.	Time					Position			
			Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth
				I	II	III	Ia				
1930.								S.	E.		
Oct.	4	353	6.20	7.05	7.45	—	—	0—33.5 0—38.8	129—07.8 129—07.1	6.00 8.20	1872
	6	354	10.00	10.33	—	—	—	1—09.5 1—09.8	129—11.3 129—10.4	9.45 10.55	579
	6/8	354a	13.40	14.22	14.55	—	—	1—29.2	129—10.3 ¹⁾	—	1365
	8	355	12.50	13.36	14.20	—	—	2—01.1	128—43.2	12.30 15.00	2049
	10	356	—	14.59	15.55	—	—	4—07.4	130—16.9	14.25 17.00	—
	11	357	10.45	11.23	12.00	—	—	4—16.4 4—16.2	129—42.1 129—42.0	10.29 12.28	1579
	11	358	15.55	17.42	18.25	—	—	3—59.0 3—54.6	129—39.2 129—37.8	15.15 19.10	4467
	11/12	359	22.28	23.30	0.15	—	—	3—40.4 3—37.0	129—34.8 129—35.3	22.00 1.10	3549
	12	360	2.16	2.50	—	—	—	3—30.2 3—29.3	129—33.5 129—33.9	1.55 3.15	1093
	12	361	18.18	19.05	19.43	—	—	3—51.9	128—50.2	17.55 20.25	2629
	22	362	5.55	7.55	8.53	11.12	—	5—34.8 5—35.4	130—55.4 130—56.8	4.50 13.25	7326
	23	363	0.22	1.00	1.30	—	—	6—02.2	131—52.0	0.10 1.50	898
	23	364	6.05 7.30	6.40	7.08	—	—	6—26.9 6—26.0	131—40.8 131—39.4	5.44 7.40	1071
	23/24	364a	12.25	—	—	—	—	6—27.0	131—30.5 ¹⁾	—	4435
	24	364b ²⁾	—	18.57	19.45 ³⁾	—	—	6—22.4 6—22.0	131—28.0 131—27.1	18.30 20.35	—
	25	365	2.55	4.10	4.50	6.15	8.17	6—32.4 6—33.8	130—44.6 130—43.3	2.00 8.40	6313
	25	366	—	13.17	14.08	—	—	6—19.5 6—19.1	130—13.4 130—12.6	12.50 15.05	—
	25	367	—	22.05	22.50	—	—	6—52.3 6—52.1	130—10.1 130—09.5	21.40 23.45	—
	26	368	5.55	6.43	7.28	—	—	7—33.0	130—21.5	5.30 8.10	2451
	27/28	369	23.12	0.18	0.55	1.55	—	7—24.0 7—23.7	129—16.6 129—17.0	22.40 3.05	4468
	28	370	8.00	8.40	9.17	—	—	8—00.0 8—00.3	129—11.6 129—11.1	7.40 9.50	1685
	29	371	—	1.37	3.50	—	—	7—38.4	128—35.4	1.00 4.40	—

¹⁾ Anchor-station, mean position.

²⁾ Table I, Vol. II, Part 2, Ch. I, p. 54, column 2: 364b should be 364a.

³⁾ Series I and II after weighing anchor.

Year Date	Station Nr.	Time						Position			
		Wire soun- ding	Serial observations				Lat.	Long.	Time	Depth	
			I	II	III	Ia					
1930.								S.	E.		
Oct.	29	372	7.27	8.18	8.55	—	—	7—22.9	128—31.5	7.20	940
								7—22.8	128—30.9	9.15	
	30	373	6.15	8.06	9.00	—	—	7—29.6	128—02.1	5.40	4058
								7—29.2	128—01.6	10.00	
Nov.	1	374	10.10	11.18	11.54	—	—	7—57.7	127—30.0	9.35	2509
								7—57.3	127—29.9	12.25	
	1/2	375	23.05	23.35	0.09	—	—	8—16.7	127—30.7	22.45	1422
										0.40	
	2	376	17.45	18.35	19.25	—	—	7—54.9	126—59.3	17.15	3292
								7—55.2	126—59.3	20.25	
	3	377	7.00	7.57	8.45	—	—	8—14.7	126—12.5	6.30	3347
								8—14.8	126—12.2	9.40	
	4	378	—	4.35	—	—	—	8—53.0	124—18.5	4.15	—
										5.10	
	4	379	17.25	18.30	—	—	—	9—27.9	122—42.2	17.00	3320
										18.55	
	4/5	380	23.32	0.28	1.15	—	—	8—57.5	122—36.0	23.00	3312
								8—57.0	122—36.3	2.00	
	5	381	3.54	4.28	—	—	—	8—46.4	122—34.9	3.30	1016
								8—46.4	122—35.5	4.40	
	11	382	8.25	9.43	10.27	—	—	12—09.0	119—53.1	7.30	3492
								12—09.6	119—51.2	11.30	

Summarising:

353 ordinary stations.

8 anchor-stations.

11 wire soundings only.

1 biological observations only.

b. ANCHOR-STATIONS.

Underneath the positions are given that the anchored ship successively took up according to observations; for calculating the mean position no use was made of the results of astronomical observations that had not been made at about the same time. These are marked by an asterisk.

Station Nr.	Year Date	Position		Time
		Latitude	Longitude	
	1929.	S.	E.	
39a	Aug. 8	1—14.3	118—20.0	18.30
	" 9	1—13.6	118—20.3	5.30
	" 9	1—14.9	118—22.1	18.30
	" 10	1—14.1	118—20.6	5.30
	" 10	1—14.2	118—21.2	12.00
	" 10	1—14.0	118—19.5	18.30
135a	Nov. 18	10—07.8	121—18.4	5.20
	" 18	10—08.0	121—20.0	12.00*)

Station Nr.	Year Date	Position		Time
		Latitude	Longitude	
	1929.	S.	E.	
135a	Nov. 18	10—06.9	121—17.8	18.50
	" 19	10—07.5	121—18.2	5.20
	" 19	10—07.0	121—17.1	18.50
	" 20	10—07.1	121—17.0	18.50
	" 21	10—07.8	121—17.4	5.20
	1930.			
253a	Apr. 24	1—47.0	126—59.4	6.00
	" 24	1—47.0	126—59.5	8.10
	" 24	1—47.7	126—59.2	13.00
	" 25	1—47.8	126—58.8	6.00
	" 25	1—47.8	126—59.2	16.00
	" 25	1—47.1	126—59.2	18.00
	" 26	1—48.2	127—00.0	11.30
	" 26	1—48.0	127—00.2	14.15 *)
	" 27	1—47.6	126—59.6	5.45
	" 27	1—47.5	126—59.4	8.05
		N.	E.	
308a	June 30	3—21.0	120—35.0	18.30
	July 1	3—21.8	120—37.5	18.30
		S.	E.	
312a	Aug. 14	6—24.6	112—55.6	12.00
317a	Aug. 22	7—54.9	122—12.5	5.30
	" 22	7—53.9	122—12.3	12.00 *)
	" 22	7—54.7	122—12.7	18.20
	" 23	7—55.5	122—12.2	5.40
	" 23	7—55.1	122—12.5	12.00
	" 23	7—54.6	122—13.4	18.10
354a	Oct. 6	1—28.9	129—10.3	18.00
	" 7	1—29.0	129—10.7	6.00
	" 7	1—29.1	129—10.3	8.00
	" 7	1—29.1	129—10.3	9.00
	" 7	1—29.1	129—10.4	10.00
	" 7	1—29.4	129—10.0	11.00
	" 7	1—29.5	129—10.2	12.00
	" 7	1—29.3	129—10.1	13.00
	" 7	1—29.1	129—10.8	14.00
	" 7	1—29.3	129—10.1	15.00
	" 7	1—29.1	129—10.4	16.00
	" 7	1—29.2	129—10.3	18.00
	" 7	1—29.2	129—10.3	18.00
364a	Oct. 23	6—27.3	131—30.8	14.00 *)
	" 23	6—27.0	131—30.5	18.30
	" 24	6—26.5	131—30.2	12.00 *)

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-



Fig. 1. The members of the expedition. Upper row, from left right: Lieut. van Straelen, Dr. Hamaker, Lieut. Paymaster Groot, Dr. Kuenen, Medical Officer Broekhoff, Dr. Hardon. Sitting left to right: Lieut. Engineer Gorter, Dr. Boelman, Senior Lieut. Perks, Mr. van Riel, Mrs. van Riel-Verloop, Commander Pinke, Prof. Dr. Boschma, Lieut. Veldman.

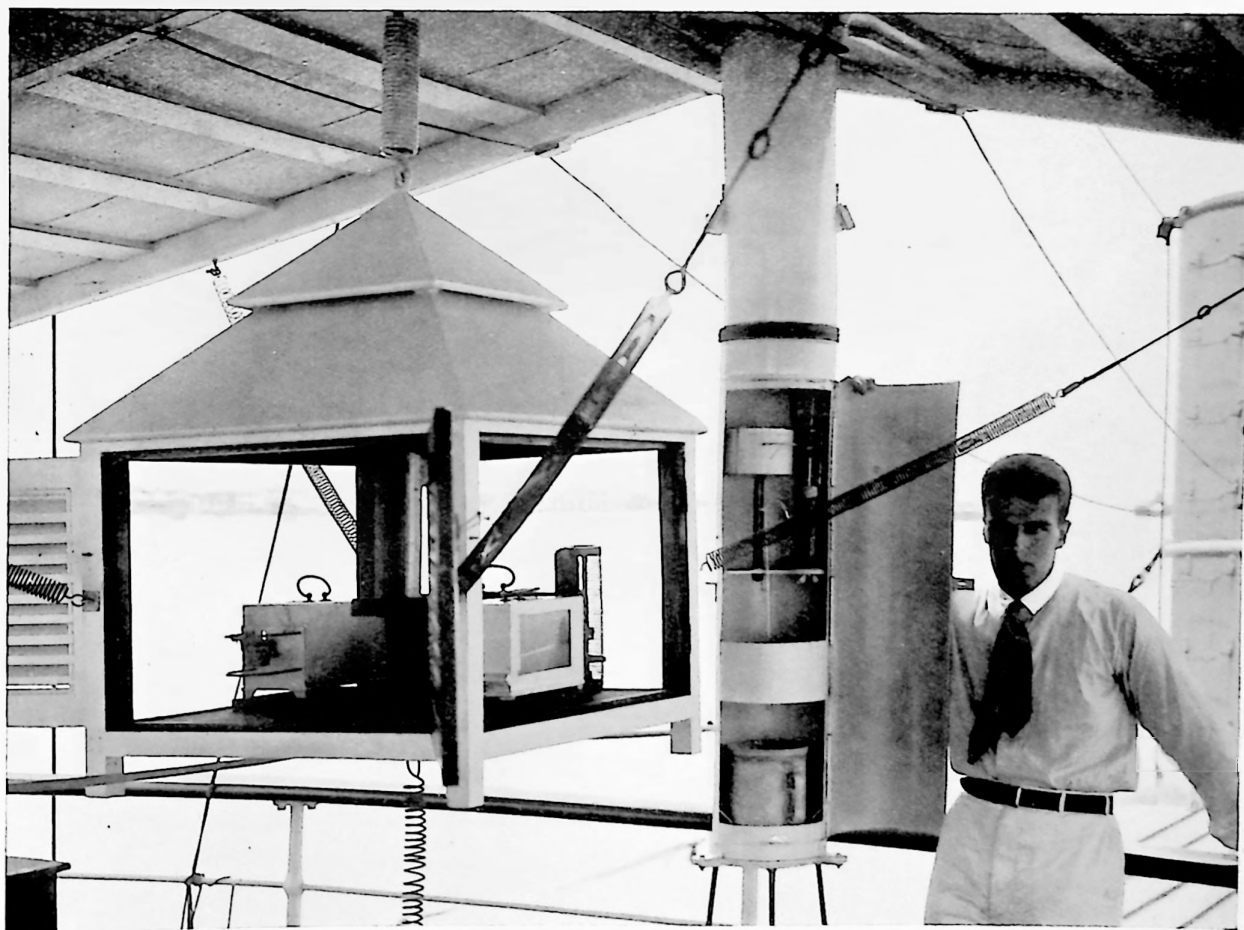


Fig. 2. Dr. Hamaker with the meteorological screen and Hellmann's registering rain-gauge on the compass deck.



Fig. 1. The roads of Koepang. Island of Timor.

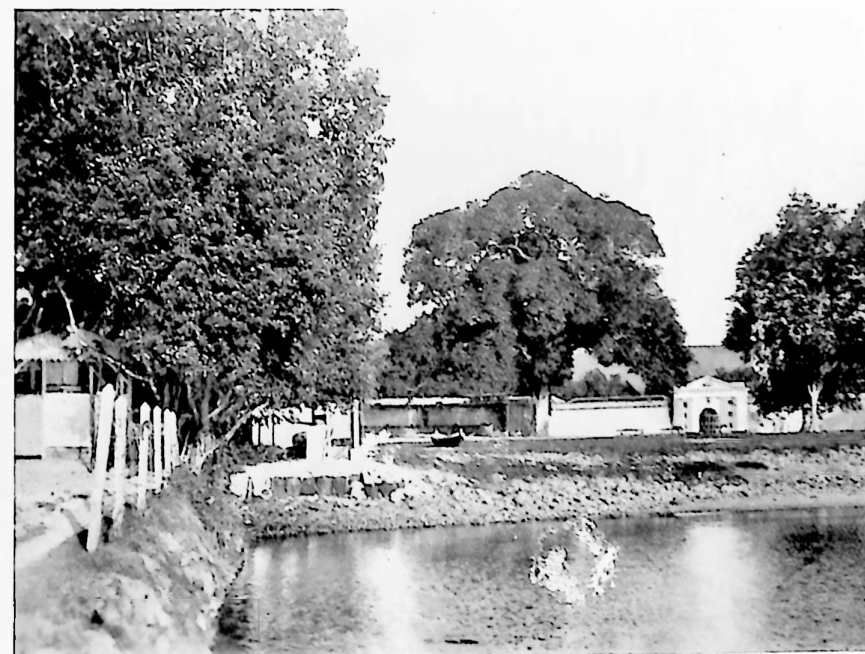


Fig. 2. The entrance to the old fortress at Ambon.

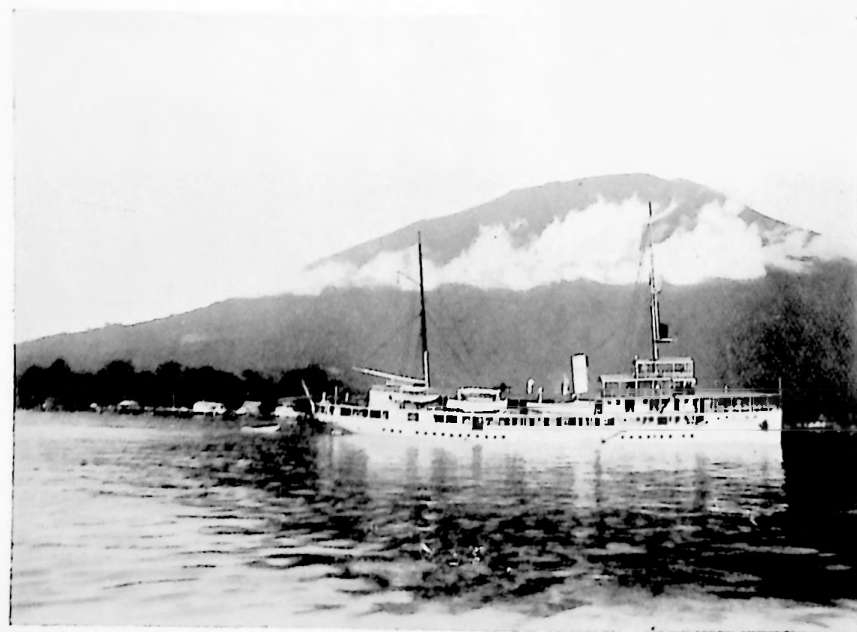


Fig. 3. The peak of Ternate.



Fig. 4. The roads of Makassar with a typical Makassar-perahoe in the foreground.



Fig. 1. Dinner-time in the leader's cabin. In the background our boy Kartodiardjo.



Fig. 2. Lodging ashore during the repairs at Soerabaia.



Fig. 3. Little room for a moment's rest during the hot hours.



Fig. 4. Commander Pinke meditating.



Fig. 1. Some members of the expedition welcomed by a flute-orchestra in the volcanic island of Seroea.



Fig. 2. An unusual way for obtaining a bottom sample at an anchor-station.



Fig. 3. A pile-dwelling in the island of Groot Hertebeest.



Fig. 4. A beach village in the island of Groot Hertebeest.



Fig. 5. Makassar.



Fig. 1. A church on the Nenoesa islands.



Fig. 3. An old cemetery in the Minahassa.
The corpses are in a sitting position.



Fig. 2. A giant of the forest in the vicinity of Lembeh strait. Left to right: Hardon, Bakker, van Straelen, Kuenen and Hamaker.

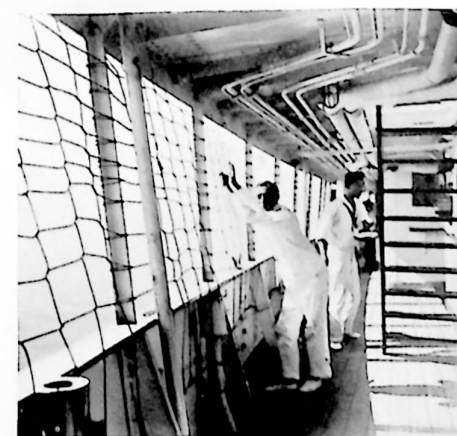


Fig. 4.
The typhoon-net. Heading for the deepest spot on earth, east of the Philippines.

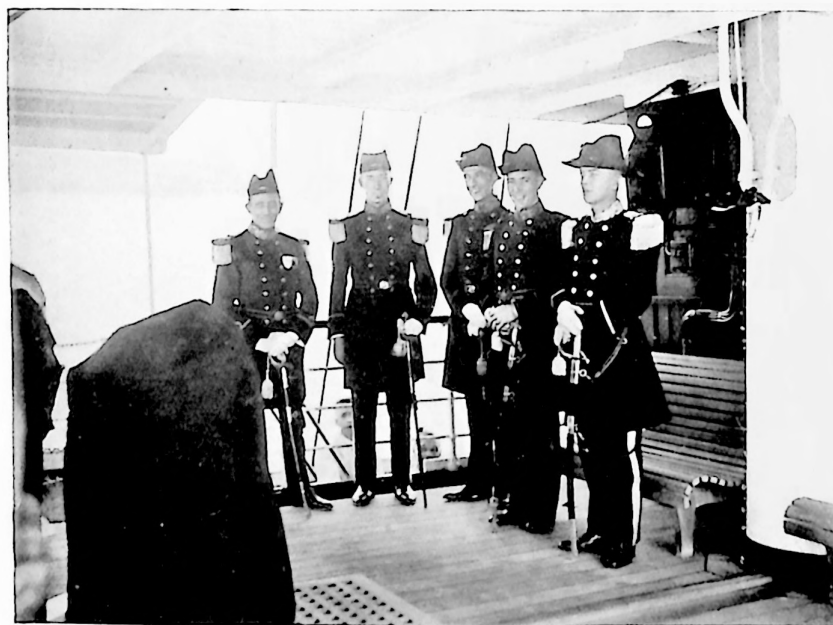


Fig. 1. The Queen's birthday. Left to right: Vos, Broekhoff, Veldman, van Straelen and Groot.



Fig. 2. The principal shop at Beo, Talaud islands. Left to right: Kuenen, Hardon and Boschma.



Fig. 3. It is not so easy to enjoy a walk ashore.



Fig. 4. The virgin forest near Beo, Talaud islands. Left to right: van Riel, Hamaker and Hardon.



Fig. 1. The road from Ambon to Soja di atas.



Fig. 2. Reaping coco-nuts. Soela islands, Vesuvius bay.



Fig. 3. One of the "belangs" on the roads of Banda.



Fig. 4. Kg. Wajaboela. Island Morotai.

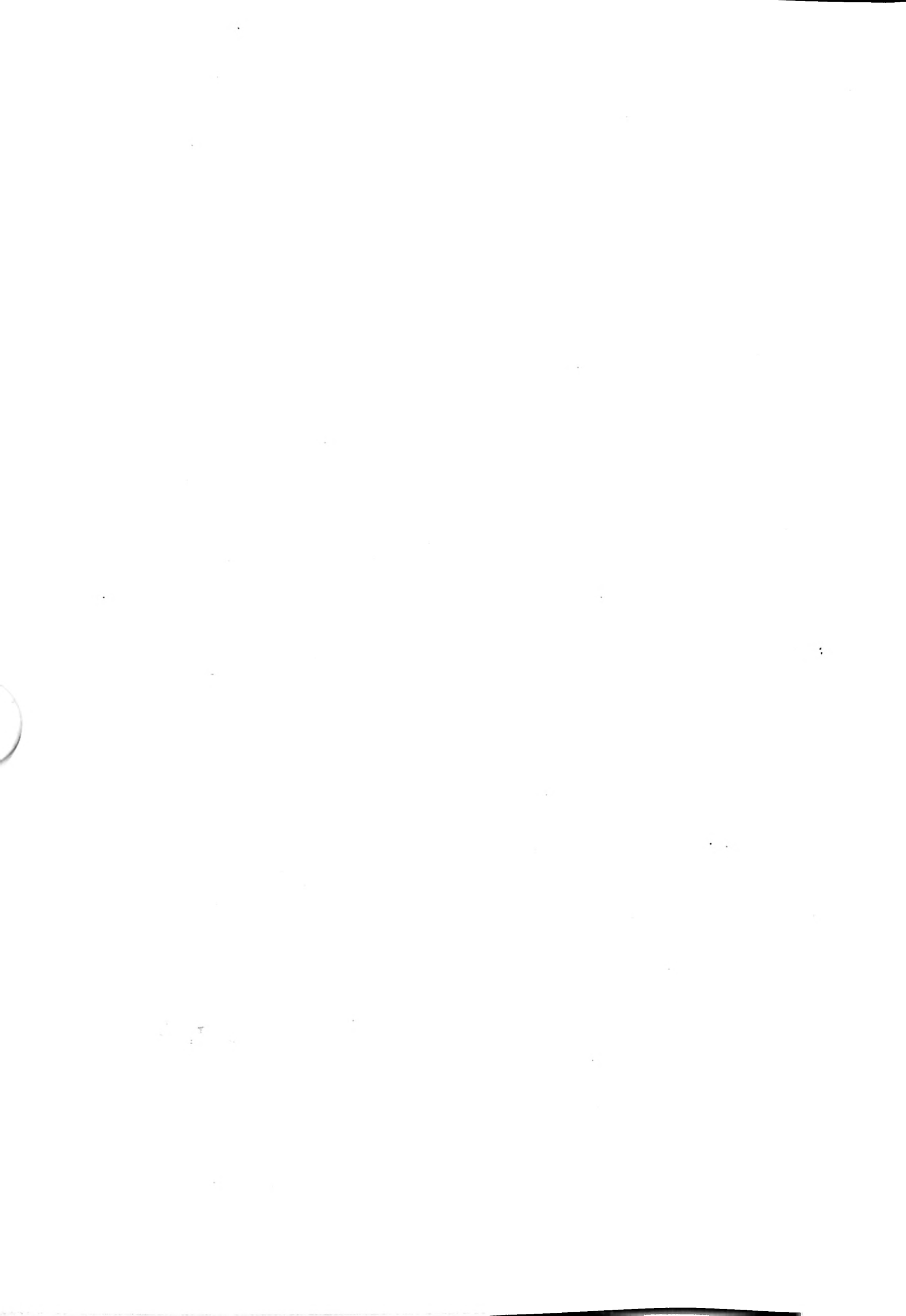




Fig. 1. When leaving the jetty at Kg. Kaledoepa, Toekangbesi islands.



Fig. 2. The lonely volcanic island of Goenoeng Api in the Banda sea.



Fig. 3. Our escort during a walk in the village Kaledoepa.



Fig. 4. The only inhabitants of the island of Goenoeng Api. Hundreds of sea-birds living there undisturbed.



Fig. 1. The barren plateau in the innerland of the island of Timor, on the way to Soë.



Fig. 2. A primitive way of salt winning at the island of Leti.



Fig. 4. Soja di atas. His mother's pride.



Fig. 3. Fishing on the reef of the island of Leti.



Fig. 5. Mrs. van Riel has luck when disembarking at Seba, island of Sawoe.



Fig. 6. Boschma and van Riel on the reef near the island of Wotap.



Fig. 1. Van Riel taking sun's radiation observations; his assistant Mas Soeprapto with the pyrheliometer in his right hand.



Fig. 2. A bottom sample of 102 cm length

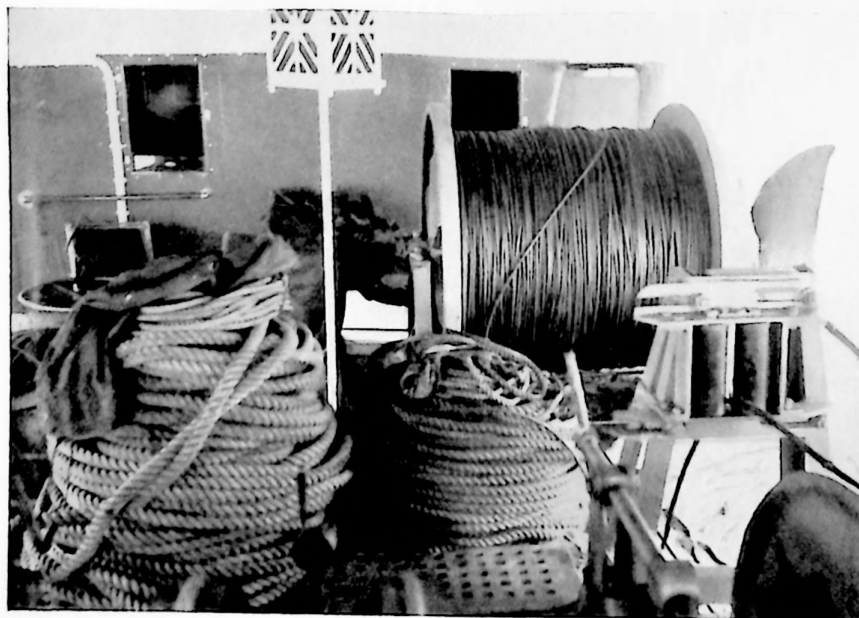


Fig. 3. The drum with 7500 m conical anchor cable.



Fig. 4. A coco-nut thief.



Fig. 1.



Fig. 2.

Two of the three beautiful mountain lakes, one red and the other yellow-green, separated by a narrow wall. Mountain Geli Moetoe on the island of Flores.



Fig. 3. Lieur's van Straelen and Milo, trying to have the latest news from a native authority in the island of Flores.



Fig. 4. On the way to the mountain lakes.



Fig. 5. Primitive dwellings in the mountains of the island of Flores.



Fig. 1. A part of the old Hindu temple Boroboedoer in the island of Java.



Fig. 2. Balinese dancing girls.



Fig. 3. Hindu temples in the island of Bali.



Fig. 4. A Balinese girl before a place of sacrifice.

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN
P. M. VAN RIEL

DIRECTEUR VAN DE FILIAALINRICHTING VAN HET KONINKLIJK
NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË
AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN
F. PINKE
LUITENANT TER ZEE DER 1^e KLASSE

1929—1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET
NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN
HET KONINKLIJK NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP



GEDRUKT DOOR EN TE VERKRIJGEN BIJ
E. J. BRILL — LEIDEN

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE



VOL. I

VOYAGE

CHAPTER IV

INVESTIGATIONS ON SHORE

BY

H. BOSCHMA AND PH. H. KUENEN

1938

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LECTURE 11

11.1

THE FIRST LAW OF THERMODYNAMICS

11.2

THE SECOND LAW OF THERMODYNAMICS

11.3

THE THIRD LAW OF THERMODYNAMICS

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CHAPTER IV

INVESTIGATIONS ON SHORE

A considerable number of excursions on shore were organised in order that the geology and biology of the reefs and coasts could be examined. When time allowed the geologist proceeded further inland also. As choice of the spots to be visited and length of the stays on land had to be fitted into the general itinerary of the expedition, the programme could not be laid down in every part according to our exact wishes. Generally speaking the length of the visits was considerably shorter than could have been wished for and many an intriguing problem and many an interesting spot had to be left unexamined. This shortage of time has laid its mark on all the work on shore. Thus smaller islands were preferably selected for geological investigation. The biological collecting was more in the nature of sampling than of a systematic bringing together of the whole fauna, while attention of the biologist was entirely restricted to the shore and reefs.

On the other hand the coasts that could be briefly explored were so widely scattered that we were able to gain a far more varied experience of the conditions of these tropical parts than many investigators with more time at their disposal, but working in a more restricted region. In this manner the mobility of the expedition partly compensated the hurry in which the investigations had to be carried through.

On our excursions to reefgroups and shores we were generally carried by a motor launch and one or two boats, with a few sailors under command of one of the officers of the Snellius. Our equipment consisted of the usual biological and geological collecting paraphernalia, diving hood, tents, lamps, water and food. During longer trips we naturally lived on the products of the land.

The geologist was always accompanied by the mantri (native surveyor) Kartodihardjo, kindly sent with the expedition by the Hoofd van den Opsporingsdienst (Head of the geological survey department) at Bandoeng; the biologist was helped by the mantri Erie from 's Lands Plantentuin (the national botanical gardens) at Buitenzorg.

The following brief account of the visits on shore is given in chronological order. As the occupation of the biologist was comparatively unvaried, it will not be repeated for each separate case. Moreover in volume VI all the data concerning the biological work are given which may be useful for investigators dealing with a part of the collected material.

On the way out from Holland to India while the ship was at anchor in the lagoon of Suvadiva atoll (3—4, V, '29) we paid the first of a long series of visits to coral reefs and reef-islands. For B ¹⁾ this was a good opportunity for comparing an oceanic reef with the East Indian and West Indian examples he was already acquainted with. For K. ²⁾, who had not yet visited the tropics, this first view of coral islands, beach rock ³⁾ and reefs was of great importance in order to gain some experience of reef-geology before starting on the actual field of investigation.

Emmahaven, Sumatra, (12—16, V, '29). Besides a trip to the famous gorge of Karbouwengat, we visited Poeloe Pisang ketjil and tested the diving hood.

¹⁾ Boschma, biologist.

²⁾ Kuenen, geologist.

³⁾ Cemented coral sand on the beach.

Java (20, V—27, VII, '29). After attending part of the IVth Pacific Science Congress and excursions following the meetings, we finished the preparations for the expedition. K. made a trip to Madoera and various parts of Java. Amongst others he visited the Kloet, the bay of Popoh, the Tankoebang Prahoe, Kawah Manoek, a number of islands in the Bay of Batavia. This group of reefs and cays formed an excellent starting point for the study of reef-geology. They had formerly been investigated by Umbgrove, who founded his conceptions on the importance of the prevailing winds for the distribution of the shingle and sand on the observations made here. They also proved to present clear evidence of recent emergence in two or three successive stages.

From 2, VII to 11, VII K. examined the G. Penanggoengan south of Soerabaja, where special attention was paid to the curious bulges around the summit of this small extinct volcano. K. was able to show that they are formed by lateral domes and do not represent parts of a former wide crater.

B. spent the greater part of the two months in Batavia at the Laboratorium voor het Onderzoek der Zee with work on reef corals. Together with Dr. J. Verwey he made several trips to different coral islands in the Bay of Batavia.

Bay of Mamoedjoe. (4—5, VIII, '29). Here there was time both for an investigation of the reef in the centre of the bay, and to collect a large number of fine specimens of alkalirocks amongst the pebbles and boulders in the kali Mamoedjoe.

Maratoea and Kakaban. (14—18, VIII '29). These two islands represent atolls raised some 100 m above sea level. We landed on one of the small islands south of Th. Babaha on the northeast coast, where B. remained until our departure, collecting material from the reefs and by means of the diving hood from somewhat deeper water. K. with Lt. Perks in the motor launch, rounded the northern point of the island and camped on the west coast. Thence they made an excursion to Kakaban and back to the base camp. Before leaving a cross-cut was made over the southern end of the raised rim of the atoll. The chief interest of this excursion for the geologist was to gain insight into the processes that take place when an atoll is raised above sea level. All pre-glacial atolls must have undergone the same influences during the low level of glacial times. The flourishing condition of the reefs in front of the gradually dissolving and abrading rim show how little reef growth need have been impeded by emergence of the atoll.

Bay of Paleleh. (21—22, VIII, '29). Here we used the diving hood and K. collected samples of the coarse conglomerate tuffs along the coast.

Sibutu archipelago. (10—15 IX, '29). In the afternoon of the 10th we entered the lagoon of the atoll east of Sibutu with the motor launch under command of Lt. van Straelen and pitched camp on the west coast of Sipankot. Until our departure B. remained in the neighbourhood, diving and collecting. Diving, especially at a steep shore of the island could be done with sufficient success, on other parts of the island the bottom was covered with very fine granular mud which obscured the view. K. investigated Sipankot and Omapui and made a trip by motor launch round the northern point of Sibutu to the east coast, where the Peak was visited. This hill was found to consist of a plutonic rock and appears to be the only spot where the foundation of these atolls peeps through the coral limestone. On the 14th our camp was taken over to the west coast of Sibutu. Before leaving, the small waterhole close to the opposite coast was viewed. In this group as at Maratoea the abrasion and denudation of raised coral reefs could be followed.

Ternate and Tidore (23—30 X, '29). K. spent the 24th—29th on Tidore investigating the northern half of this volcanic island. He was also able to make observations on the flourishing reefs that surround the coast. An interesting detail was the frequency of shingle ramparts at right angles to the coast. B. collected material from the shore and shallow water at Ternate, the mantri Erie at Tidore.

Archipelago south of Misool. (3—6 X, '29). This excursion was executed under the leadership of Lt. Veldman. Camp was pitched on the islet Kafal but a dozen other islands were also visited by K., who collected a fair number of fossils. Formerly Wanner had noted important faults between the various islands. K. was able to ascertain that broad anticlines with a strike from east to west play a no less important part in the structure of this region.

Aroe islands (11—15 X, '29). As centre of our operations we took the village at the mouth of the soengai (water coarse) Manoembai. Lt. Perks took K. and B. up this Soengai by motor launch and afterwards up a tributary and also along the Soengai Workai. Some excursions on land were also car-

ried out. Soundings and observations along the banks enabled K. to form an opinion on the mode of formation of these curious waterarms. Without doubt tidal scour is a factor of prime importance, though the initial act was evidently the drowning of a pre-existing, local drainage system. In the muddy water of one of the soengais some reef corals, belonging to different genera, were collected.

Tanimbar islands. (20—23, X, '29). While the Snellius was at anchor in the bay on the west coast of Wotap, B. occupied himself with the reefs around the small island in the centre, which has luxurious coral growth especially on the south side. K. visited this spot, made a trip round the northern and southern coast of Wotap with a detour to the coral islands Jarngoer Roel and Jarngoer Raa and climbed to the summit of Wotap. Verbeek had formerly surmised that this island was coated by coralliferous limestone, but apart from reefs raised a few dozen metres, the chief mass is composed of coarse sandstones and some limestone.

Timor. (31 X—11 XII '29). K. left Koepang for Niki Niki by motorcar on the 6th of November and proceeded from thence to Nipol on foot where he stayed for three weeks.

The latter part of the stay on Timor he spent at Baoen, that is easily accessible by motorcar from Koepang, ending up with a few days at Koepang.

As the structure of this island is far too complicated to allow of any material increase of knowledge from a short visit, K. concentrated on the collecting of fossils from the world famous Permian and Triassic deposits.

Most of the Permian fossils were obtained for nominal prices from the inhabitants. The Triassic Cephalopoda on the other hand occur chiefly in loose blocks. These were shattered by explosives by which method a great number of fossils drop out almost undamaged and a large box full could be collected in a few hours time. Many hundreds of teeth were also obtained from the Cretaceous deep sea clay, discovered by Jonker during his expedition 15 years before. Thirty packing cases of fossils could be sent to Holland by the time the Snellius returned to pick us up. Although this material has not yet been fully examined, it has already been ascertained that it contains a large number of new species. Evidently these wonderful fossiliferous strata of Timor are not nearly exhausted yet and will doubtless yield a rich harvest to future collectors and investigators.

K. concluded his visit to Timor by a trip to Poeloe Kambing, with B. to see this enormous mud volcano. It rises from the sea bottom to the south west of Koepang and is crowned by a caldera of a few hundred metres across. The likeness to a volcanic crater is enhanced by the occurrence of a number of secondary cones on the floor of the caldera, that are still slightly active.

B. went for an excursion right across Timor from Koepang to Atapoepoe, but the remainder of the time he spent chiefly on the islet Kera opposite Koepang. This enabled him to make a fairly complete survey of the reefs and of the shore and flats. Moreover Tandjong Lelinto on Timor, Hainsisi on Semaue, and the island Kambang were visited to collect material from the shores and the reefs, whilst some dredging was done in 6—15 metres off Koepang.

Postiljon islands. (20—23, XII '29). These islands are coral formations on a large atoll. We first landed on Pelokan and then camped on Sapoeke with Lt. Milo as skipper of the motor launch. From Sapoeke a few of the other islands were visited. From a geological point of view the main interest of these islands is the occurrence of a boulder rampart along the eastern edge of the reef flats. K. was able to show that they owe their formation to the growth of large coral colonies during a former higher stand of sea level. They are now being gradually washed away. In this manner they are not comparable to the shingle ramparts of the reef flats of many other reefs that are of recent formation and are being continually built up further.

Bima (24—26, XII, '29). K. collected rock samples on a trip to Sapeh. Some biological material was collected near Bima, on the islet Kambing and near Sapeh.

Makassar. (3, II, '30). We visited a couple of reef islands close to Makassar and found conditions similar to those in the Bay of Batavia.

Paternoster islands (7—9, II, '30). We camped for a night on Aloang and afterwards the Snellius took us to Sailoes besar. In this manner several islets could be investigated. These appear to be of the same nature as those of the Postiljon group. Boulder ramparts on the eastern margin of the reef patches are generally found.

Tana Djampea. (21—22, II, '30). While the Snellius was at anchor on the west coast in the bay of Katella K. collected a number of rock samples, the most interesting of which was a leucite-lava.

This proves that the alkaline province of southern Celebes continues on beyond Tambolongang, the furthest point to which it had as yet been traced. By diving B. collected a quantity of reef corals.

Makassar (24, II—4, III, '30). By kind permission of the Assistant Resident we were allowed the use of a motor launch, so that we were able to make three day-excursions to a number of reef islands.

One of these was entirely spent on Bone Tamboeng in order to use the diving hood. K. 's observations mainly confirmed Umbgrove's conclusions concerning the influence of the westerly winds on the development of the sandcays, but he came to the conclusion that the easterly winds are also of some importance.

Batoe Ata. (6, III, '30). While B. spent the day diving on the reef of the north east coast, K. crossed the island to the southern and the eastern shores. No other rock than reef limestone was met with. The experience gained here was of importance in connection with the next investigation.

Binongko. (7—10, III, '30). On this excursion we again had the help of Lt. Perks. Our camp was placed on a low sand flat on the north eastern shore, where some comfortable caves provided excellent quarters. B. remained in this neighbourhood and dived repeatedly, especially at a ridge at some distance from the shore, the highest part of which is about 2—3 m below sea level. K. went for several tours, one starting on the east coast where he was brought by motor launch. His chief occupation was an accurate measurement of the levels of the countless reef terraces that are met with on the outer slopes. Along six sections the measurements showed that a correlation was possible, and that the various terraces are quite level. Evidently the island has been raised in successive stages without tilting or bending.

Soela islands (18—19, III, '30). K. visited the south eastern corner of Taliaboe and the south western cape of Mangoli. Besides observations on the geology of the shore, a collection of fossils was made on the latter island. Biological material was collected on the shore and in the shallow water of the islet Pasi Ipah.

Ternate (27, III—3, IV '30). Owing to an attack of malaria K. was not able to finish the survey of Tidore, the southern half of which had not been examined on the first occasion.

Seroea (10, IV, '30). B. remained at the shore, while K. climbed to the summit of this small, active volcano. A number of small lava plugs were found at the top, but no distinct crater. Solfatara have attacked the rocks at several places on the slopes.

Gn. Api near Wetar (14, IV, '30). This small island is the summit of a huge submarine volcano, rising directly from the sea floor at a depth of over 4000 m. It is peopled by enormous flocks of sea birds, but the climate does not allow of the formation of guano. The crater is opened on one side and two more great land slides have occurred on other sides of the island, one of which is submarine only.

Obi latoe. (23—27, VI, '30). While the expedition was occupied at the anchor-station in 1°47'.5 S, 126°59'.5 E, Lt. Veldman conducted us to our camp on P. Toesa on the north eastern corner of Obi latoe. B. busied himself on the reef and along the shore. K. examined P. Toesa and during the following days he landed at 14 points along the coast of Obi latoe. At three of these a short trip inland was made. Most of the island is composed of basic plutonic rocks. Amongst these a fine orbicular gabbro was met with, probably the most basic rock with orbicular structure yet known. The formation of serpentine by contact-metamorphism from the basic rocks where an andesite intrusion occurs, is also worthy of note.

Oeliassers (1—7, V, '30). During the stay at Ambon B. collected material on the shore and in the shallow water in the Bay of Ambon, near the town, and at Wainitoe. On the 2nd K. left for Toelehoe by car, sailed from thence by prauw to Pelauw on the north coast of Haroekoe, remaining there until the Snellius fetched him off. Forty years before Martin had examined the southern and western parts of this island. K. therefore concentrated on the northern and eastern parts, making also several tours deeper inland. The usual collection of samples was made.

Nanoesa islands (20—21, V, '30). This short visit enabled us to see the reefs around two of these small islands. A toothed reef edge and negro-heads are found here, two phenomena that are due to the position of the group, exposed to oceanic swell and to occasional typhoons.

Kaoe bay. (28, V, '30). K. brought together a collection of rock samples and examined curious sub-recent breccia's formed on the shore. Corals and other material of the reef and the shore were collected at Ake Selaka.

Morotai (30, V—11, VI, '30) K. was put on shore at Wajaboela where he was subsequently fetched again after the Snellius had been at Ternate for a week. He followed the coast northwards to Tjio and journeyed from thence to Hapo by prauw. After an excursion inland he returned to Tjio. A trip was then undertaken up the river Ake Tjio on bamboe rafts for two days. From there he returned to the coast at Tilei on foot and sailed back to Wajaboela. The last days were spent visiting a number of reef islands off the south western coast. K. only met with volcanic rocks and a few limestone boulders on the main island. No sedimentary strata were found in situ. On the reef-islands clear signs of recent emergence are to be seen.

During this period B. collected some material at Ternate, chiefly by diving at depths of 4 to 8 m.

Talau islands (14—21, VI, '30). By kind permission of the radja we were allowed the use of two rooms in the „hospital” at Beo. B. remained in these quarters as a convenient centre for work on the reefs. K. studied the geology of the neighbourhood and crossed over to Reinis for two days. Although the available time was too short for detailed surveys, K. nevertheless believes he may assume that the structure of Karakelong is more complicated than Roothaan concluded from his field work carried out some time before. Several indications of faults were encountered, so that block-faulting has influenced the position of the strata. Here again as on the Nenoesa islands toothed reef edges and negro-heads characterise the reefs, open to the ocean.

Flores. (18—19, VIII '30). B. having left for Holland, K. was afterwards always accompanied by the mantri Erie who collected biological specimens along the coasts. Besides the plutonic rock from the neighbourhood of Papang that had formerly been discovered, K. met with Tertiary limestones and contactmarble. Although the junction between these rocks is not exposed, there are indications that the plutonic rock is responsible for the alteration of the limestones and must therefore be of Tertiary age.

Kaledoepa (27, VIII '30). K. examined the central parts of this island, belonging to the Toekang besi group. He found that the marls sighted by Hetzel form a low anticline running along the main axis of the island.

Ambon (10—17, IX, '30). K. was taken by motor launch to Laha on the opposite shore of the bay of Ambon and spent 5 days examining the southern coast of Hitoe. Verbeek earlier found volcanic rocks. Further inland K. discovered older rocks, partly of sedimentary origin, comparable to those of the peninsular of Laitimor.

Strait Lembeh (25, IX '30). There was only time for a walk along the slopes of the coast.

Morotai (1—2, X, '30). The former survey made by K. was extended up to the northern point of the island.

Boo islands (4—5, X, '30). There was only opportunity for a swift survey of a few of the reef islands. The larger of these appear to be mere rings of sand and shingle around wide mangrove swamps.

Leti. (31 X, '30). K. spent some time on the coastal geology, where beach sandstone and signs of recent emergence called for attention.

Kisar (2, XI, '30). This island makes the impression of a raised barrier reef, but closer examination led K. to the conclusion that there is only a thin veneer of reef limestone on schistose rocks. The latter material has yielded more readily to subareal erosion, with the consequence that the parts protected by reef rock stand out as a rim round the low hilly ground behind. K. crossed the island, returning to West coast by a different route and thus gained a general impression of the various rocks exposed in the interior.

Flores (5—8, XI, '30). K. made two excursions to the Gilimoetoe the famous volcano with three craters with a red, a yellow and a blue crater lake.

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Fig. 1. Mangroves along the coast of Bongao in the Philippines.



Fig. 2. What looks like sand is actually weathered volcanic glass, as may be seen from the turbulent flow-structure. East coast of Tidore.



Fig. 3. Boat used during investigation of coral reefs along the coast of Morotai.



Fig. 4. Camping on small island opposite Obilatoe.

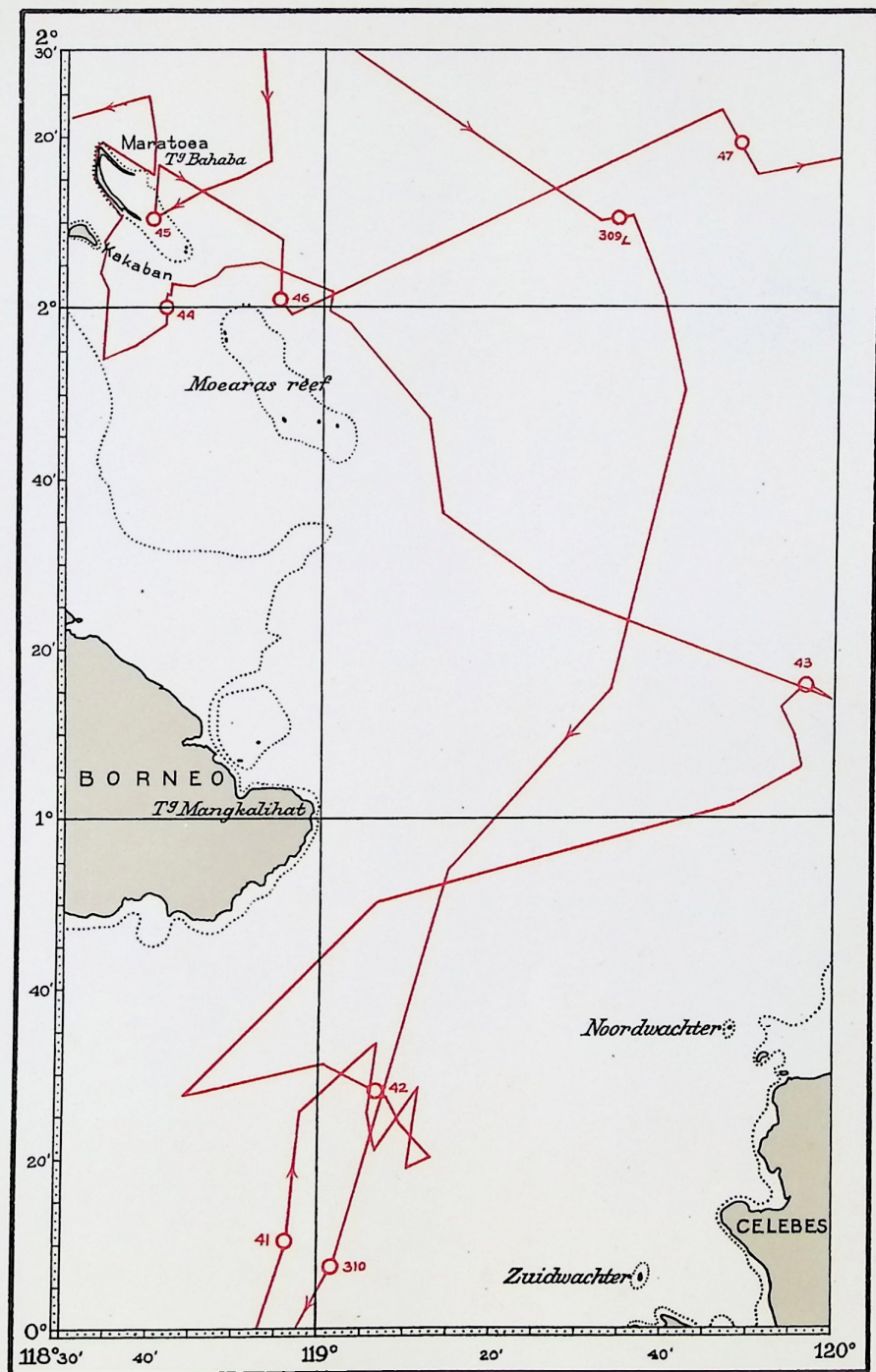


CHART I. NORTHERN ENTRANCE TO STRAIT OF MAKASSAR

10 0 10 20 30 40 50 km

Scale 1:500 000

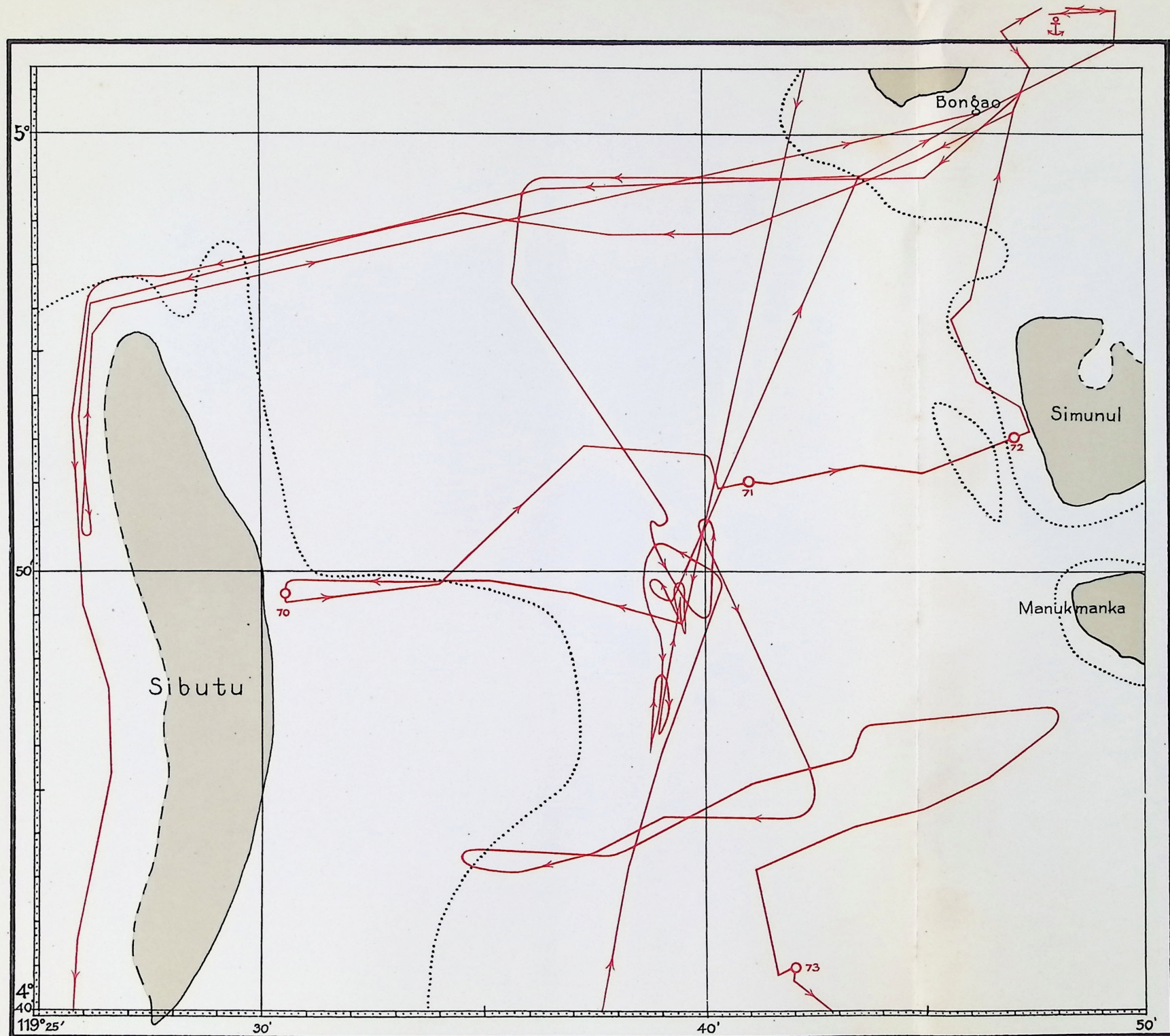


CHART 2. SIBUTU PASSAGE

2 1 0 2 4 6 8 10 km

Scale 1:200 000

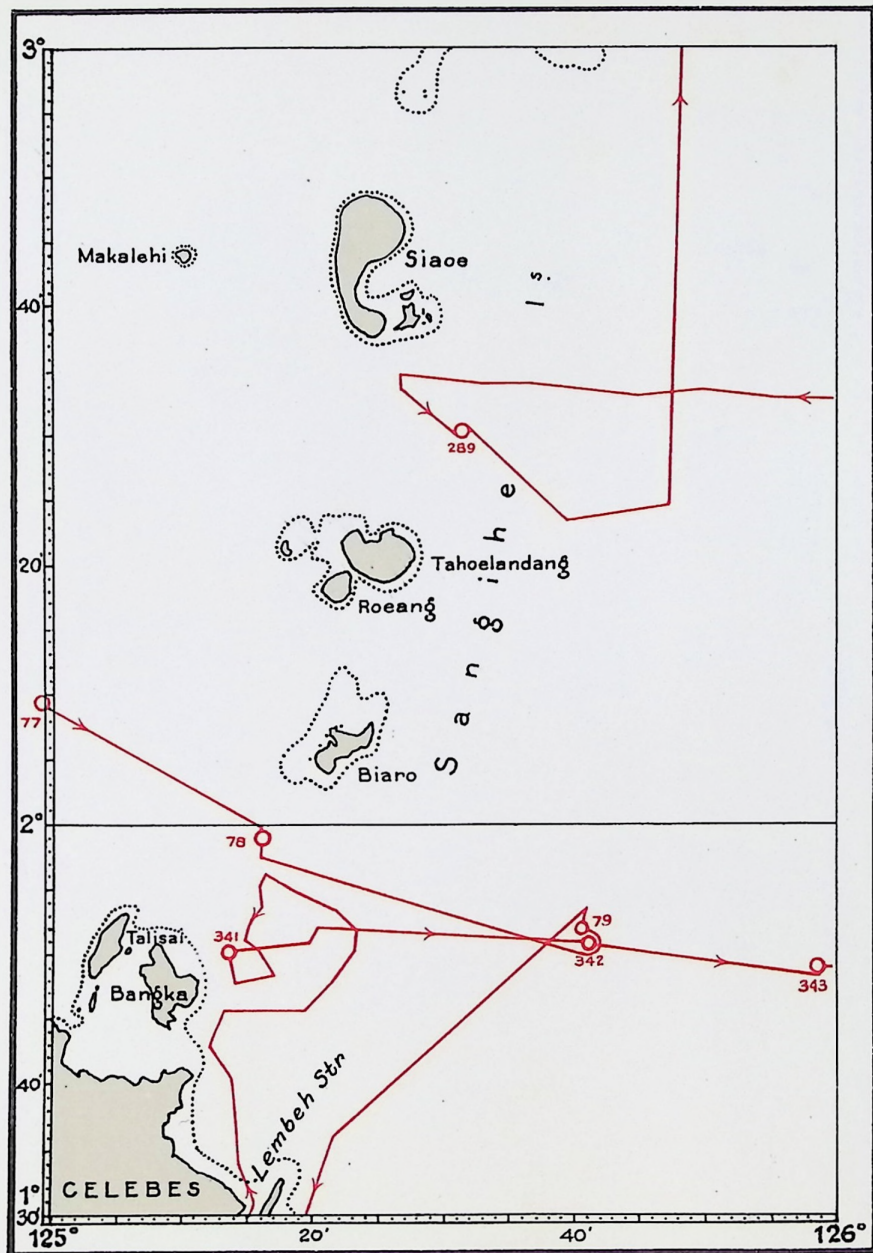


CHART 3. PASSAGES BETWEEN N.E. CELEBES AND SIAOE I.

10 0 10 20 30 40 km

Scale 1:1 000 000

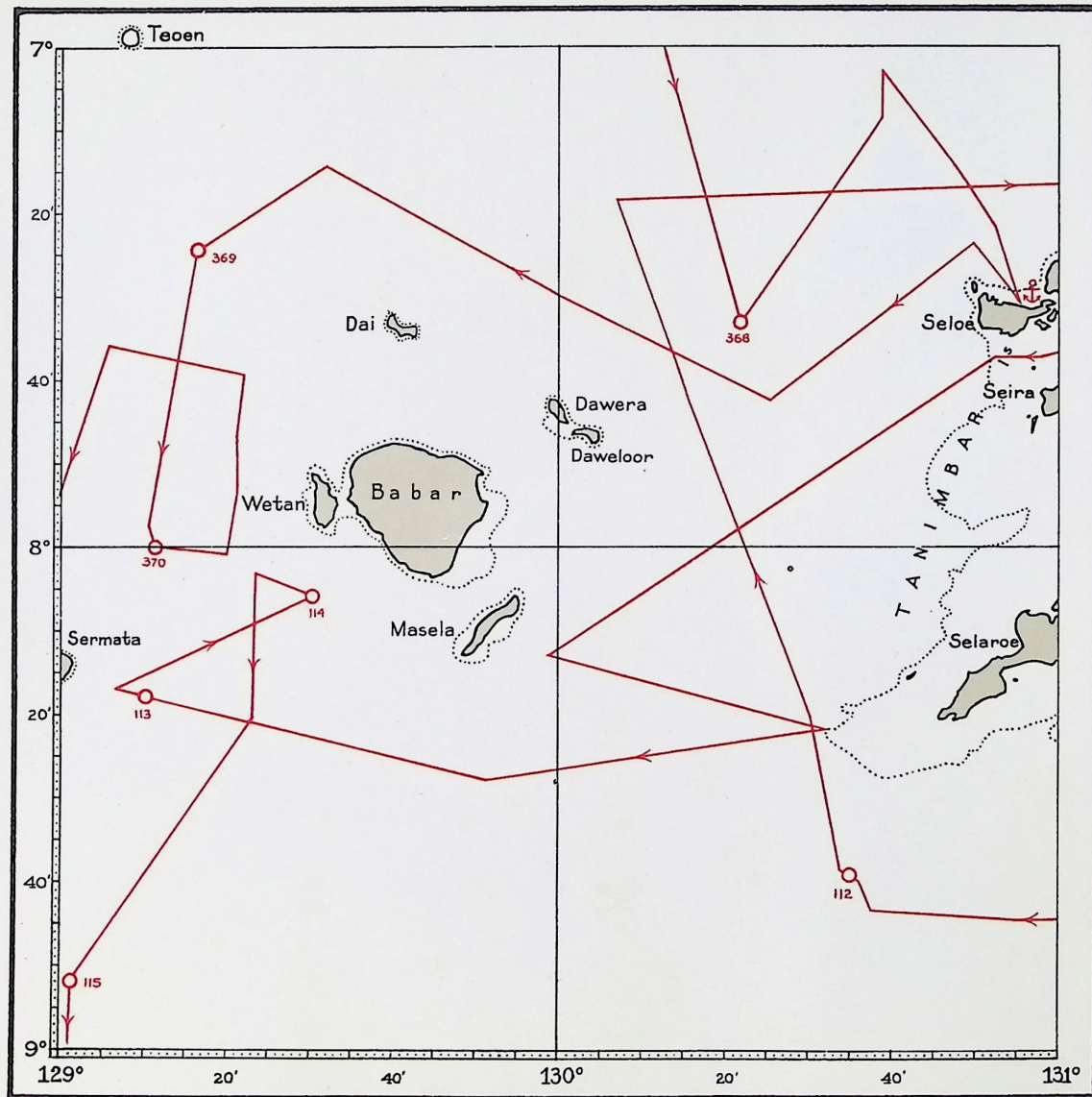


CHART 4. PASSAGE BETWEEN TANIMBAR I. AND BABAR I.

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Scale 1:500 000

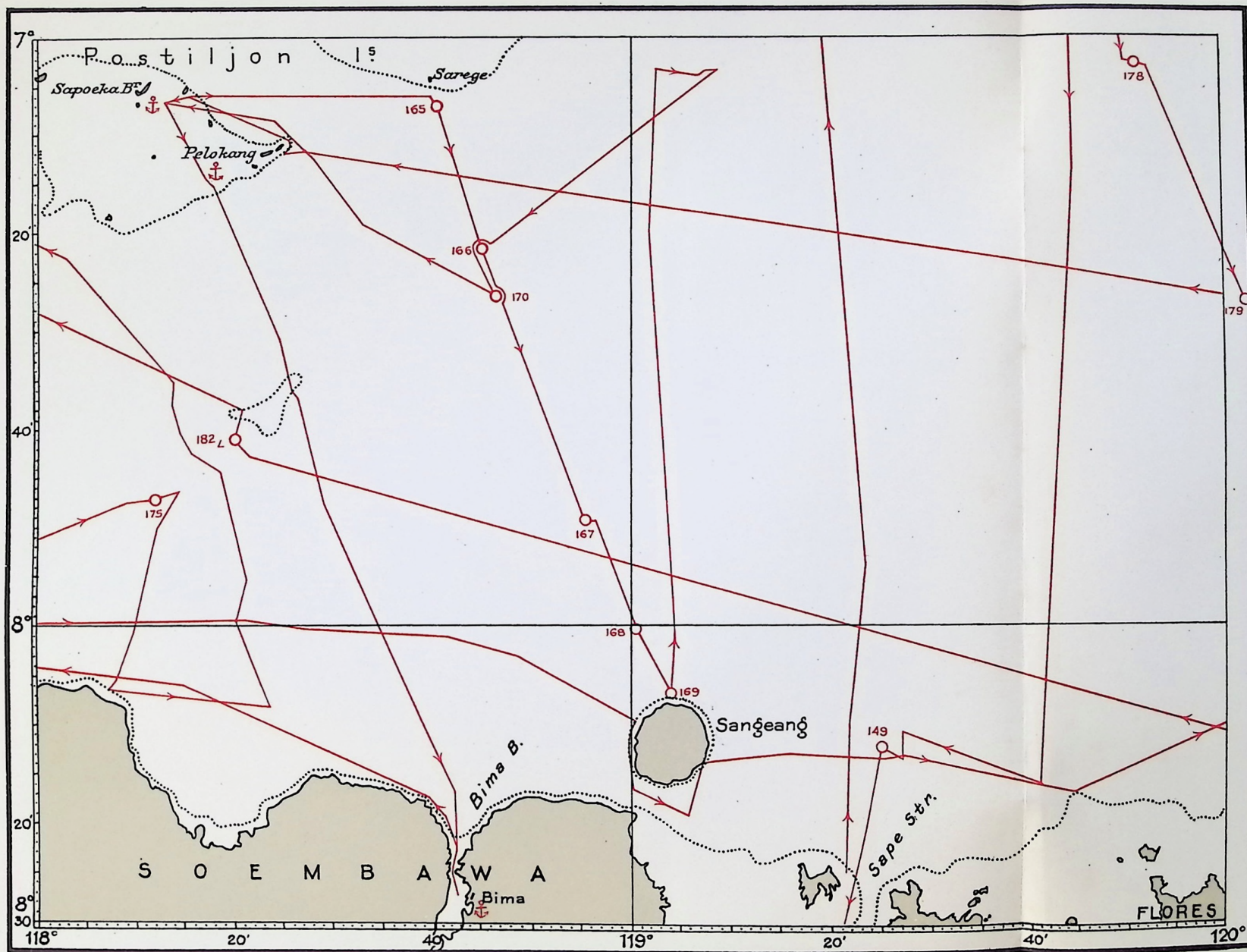


CHART 6. WESTERN PART OF THE FLORES SEA

10 0 10 20 30 40 50 km

Scale 1:1000 000

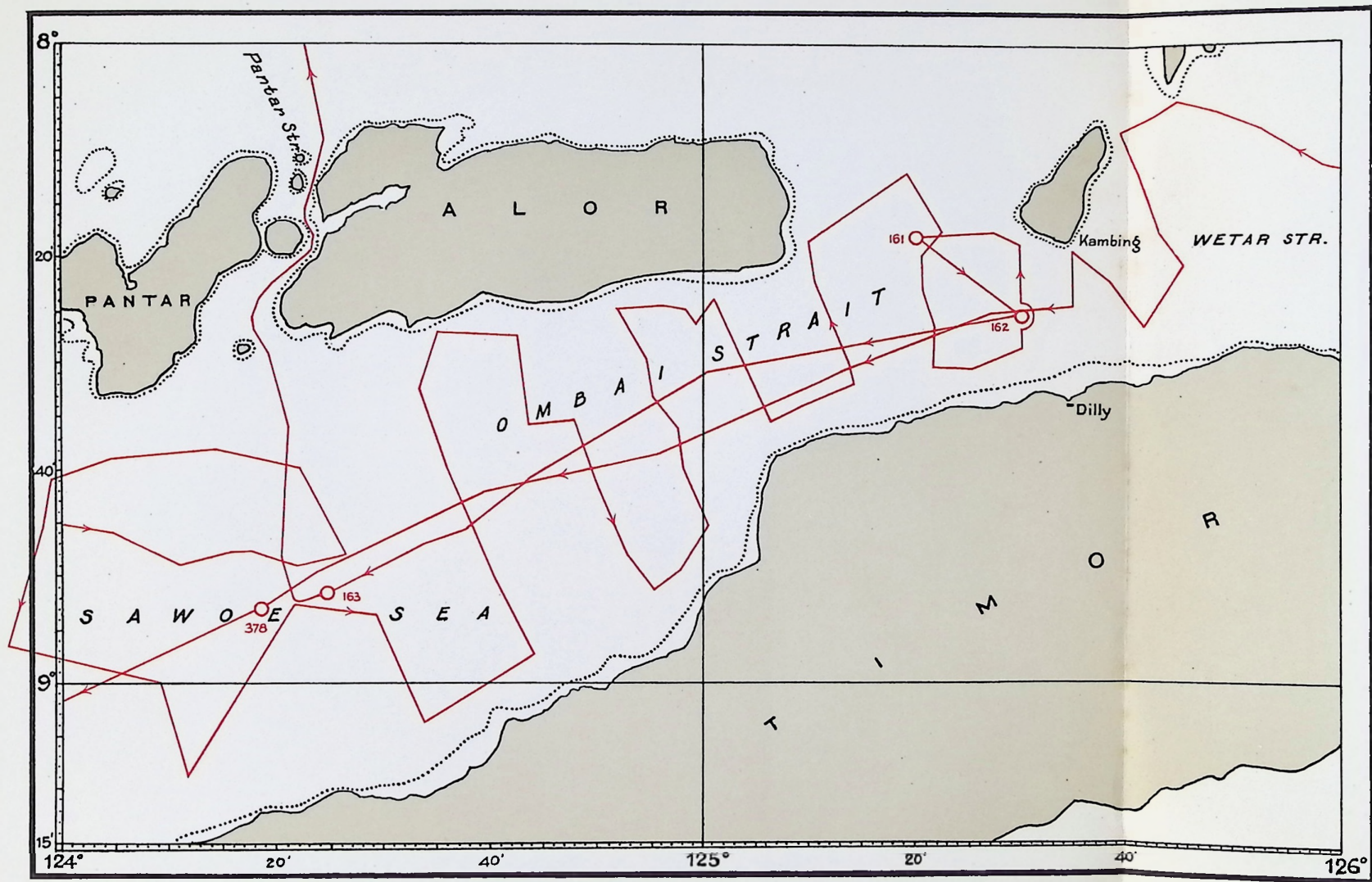


CHART 7. OMBAI PASSAGE

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Scale 1:1000 000

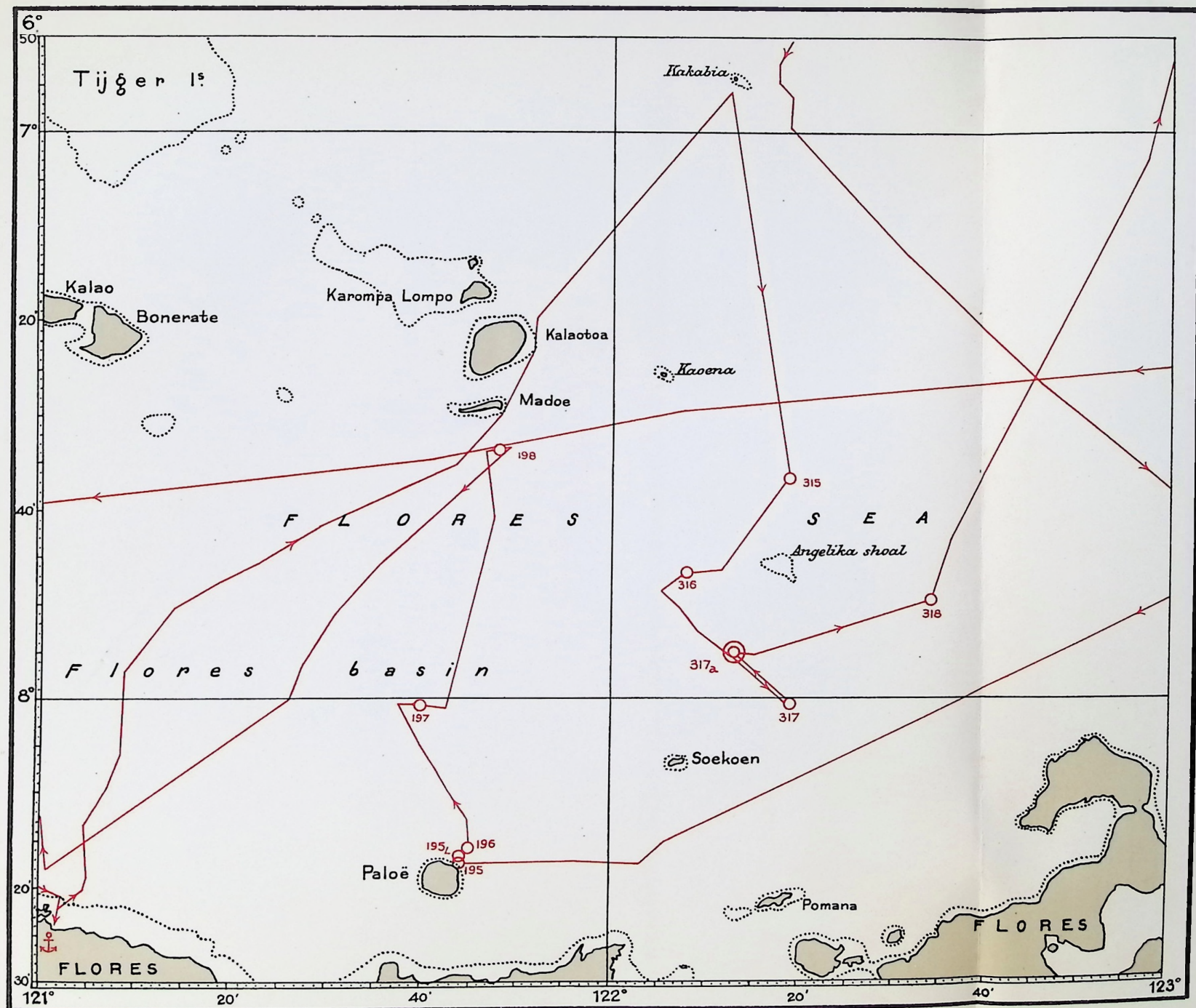


CHART 8. EASTERN PART OF THE FLORES SEA

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Scale 1:1000 000

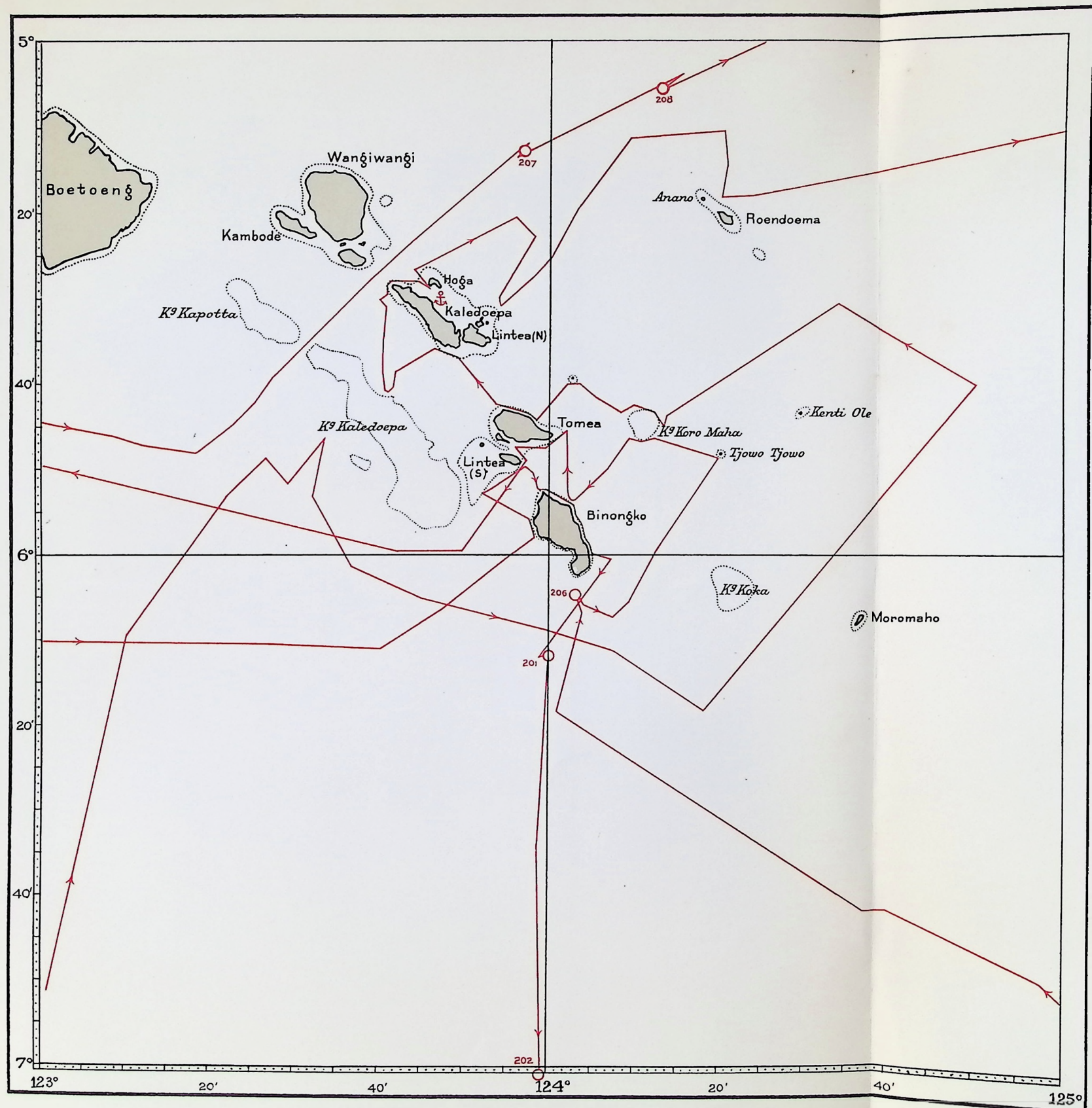


CHART 9. TOEKANGBESI ISLANDS

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Scale 1:1 000 000

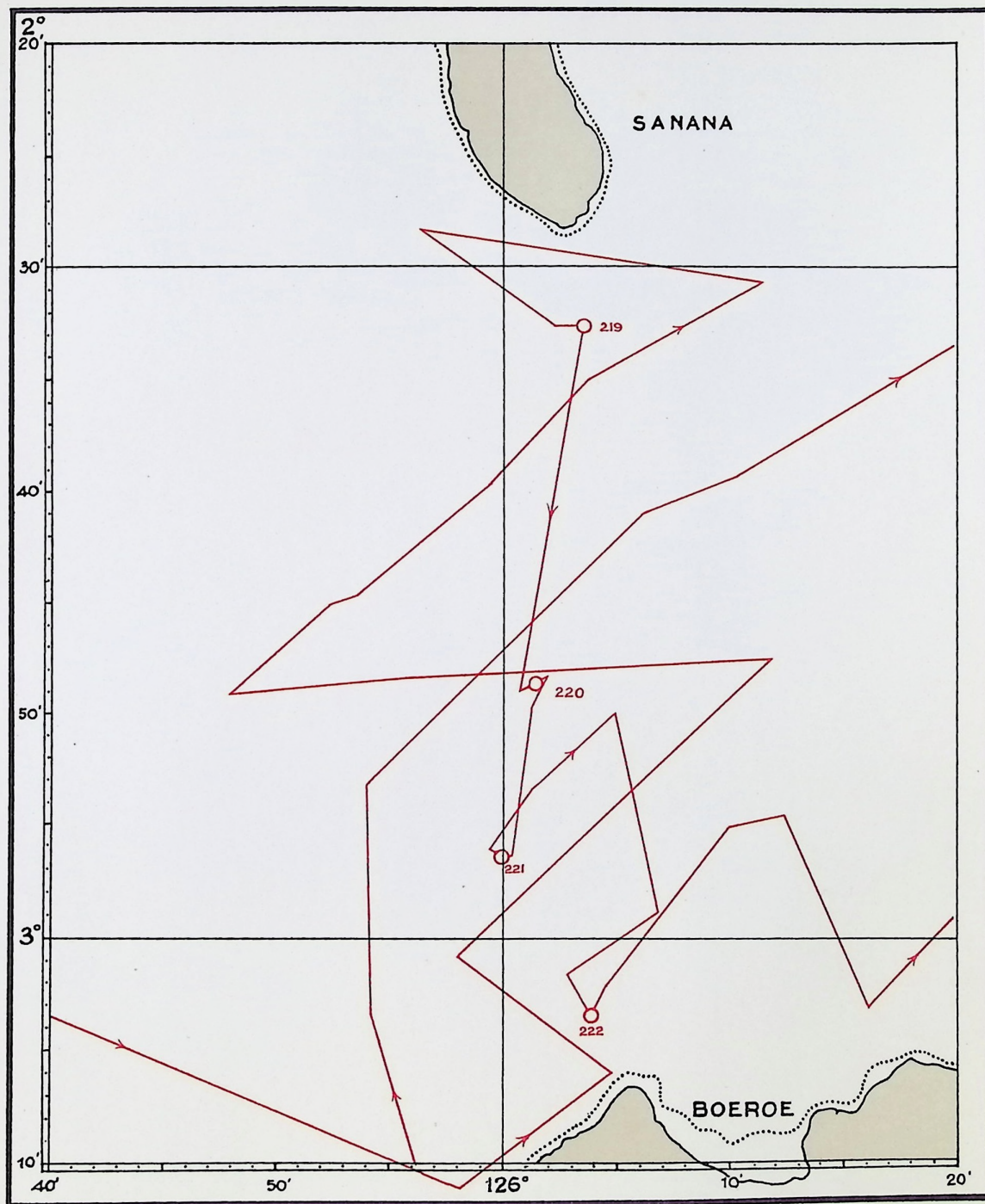


CHART 10. PASSAGE BETWEEN BOEROE AND SANANA

5 0 5 10 15 20 25 km

Scale 1:500 000

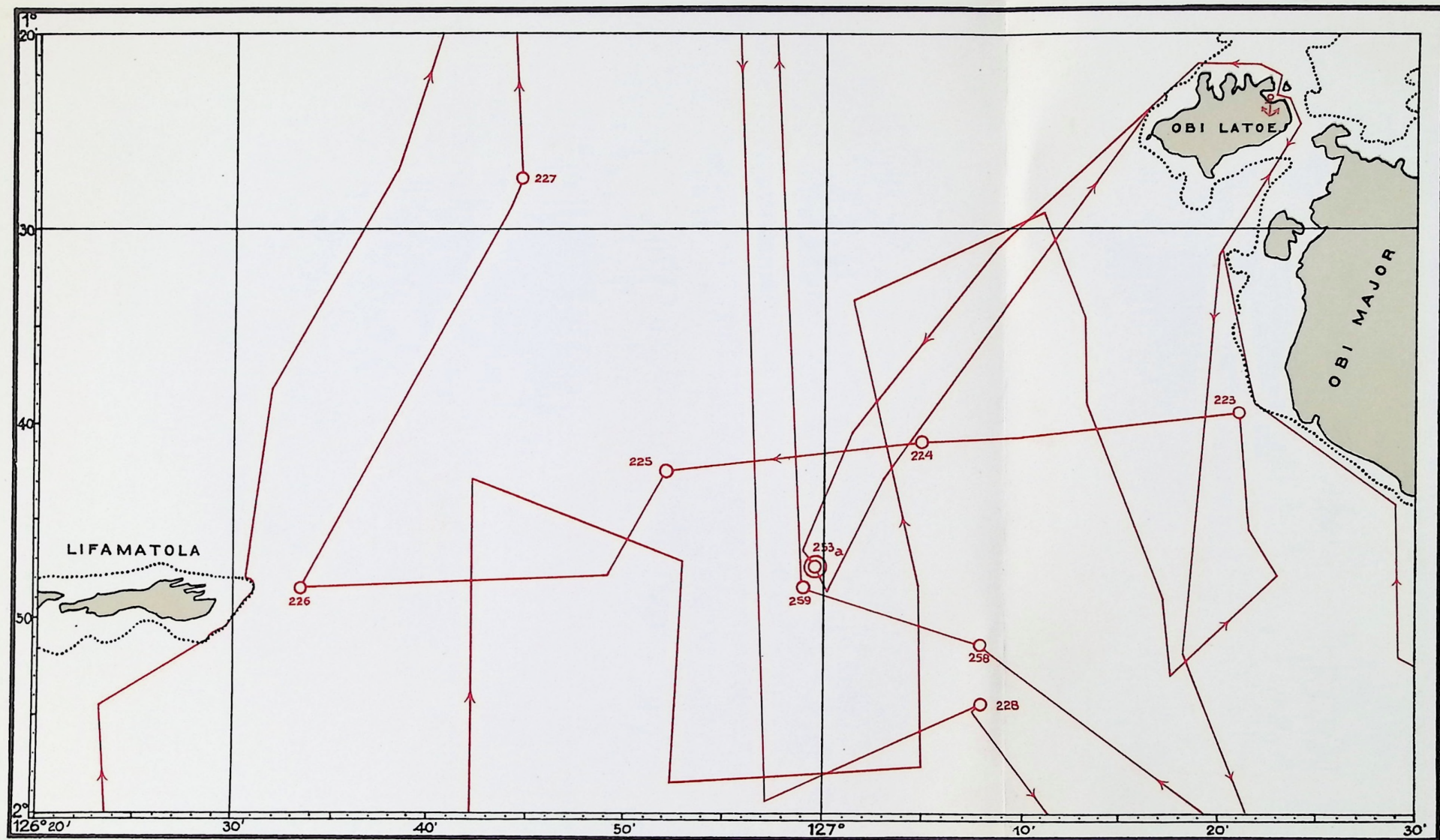


CHART II. LIFAMATOLA STRAIT

5 0 5 10 15 20 25 km

Scale 1:500 000

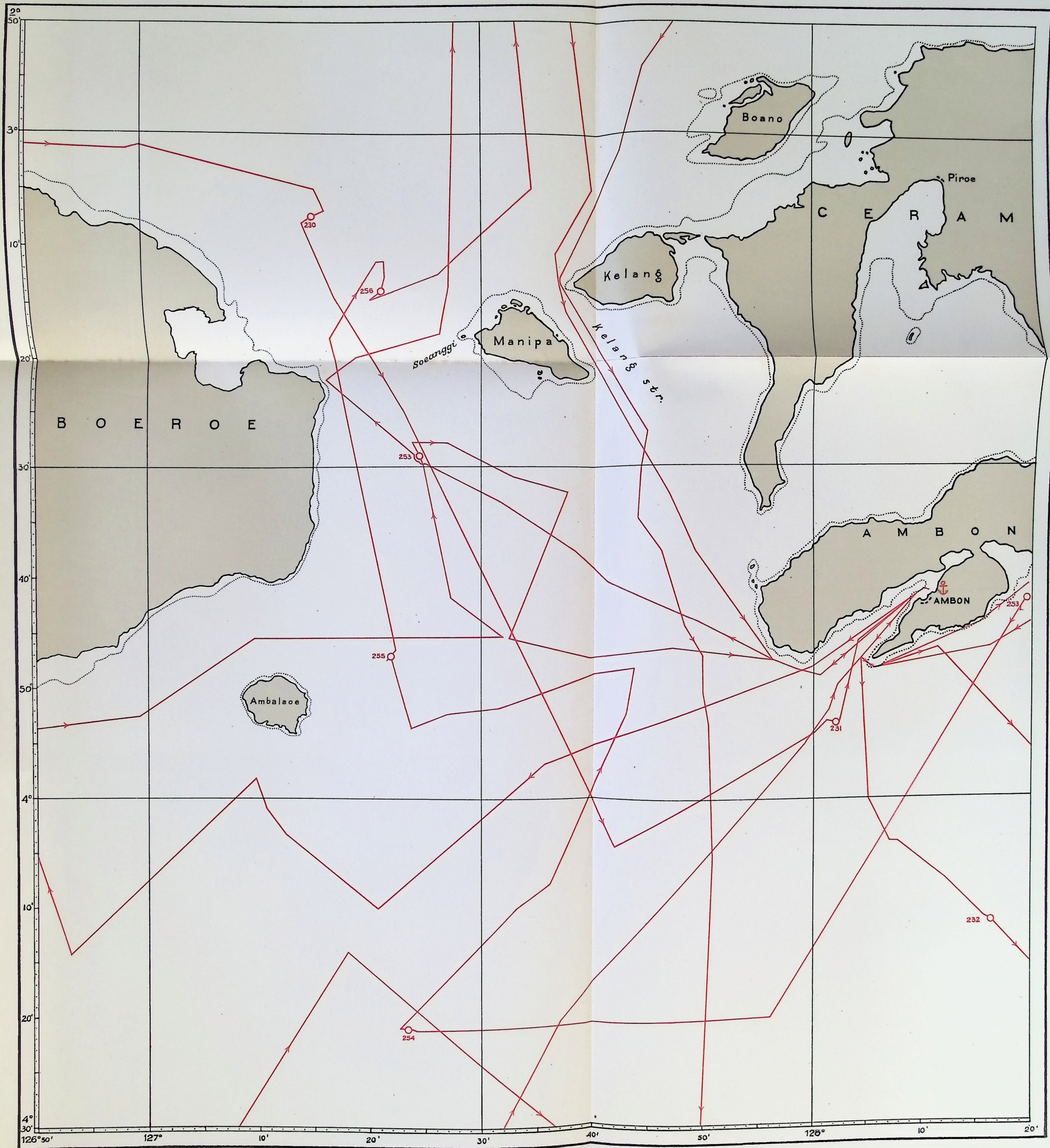


CHART 12. MANIPA STRAIT

Scale 1:500 000

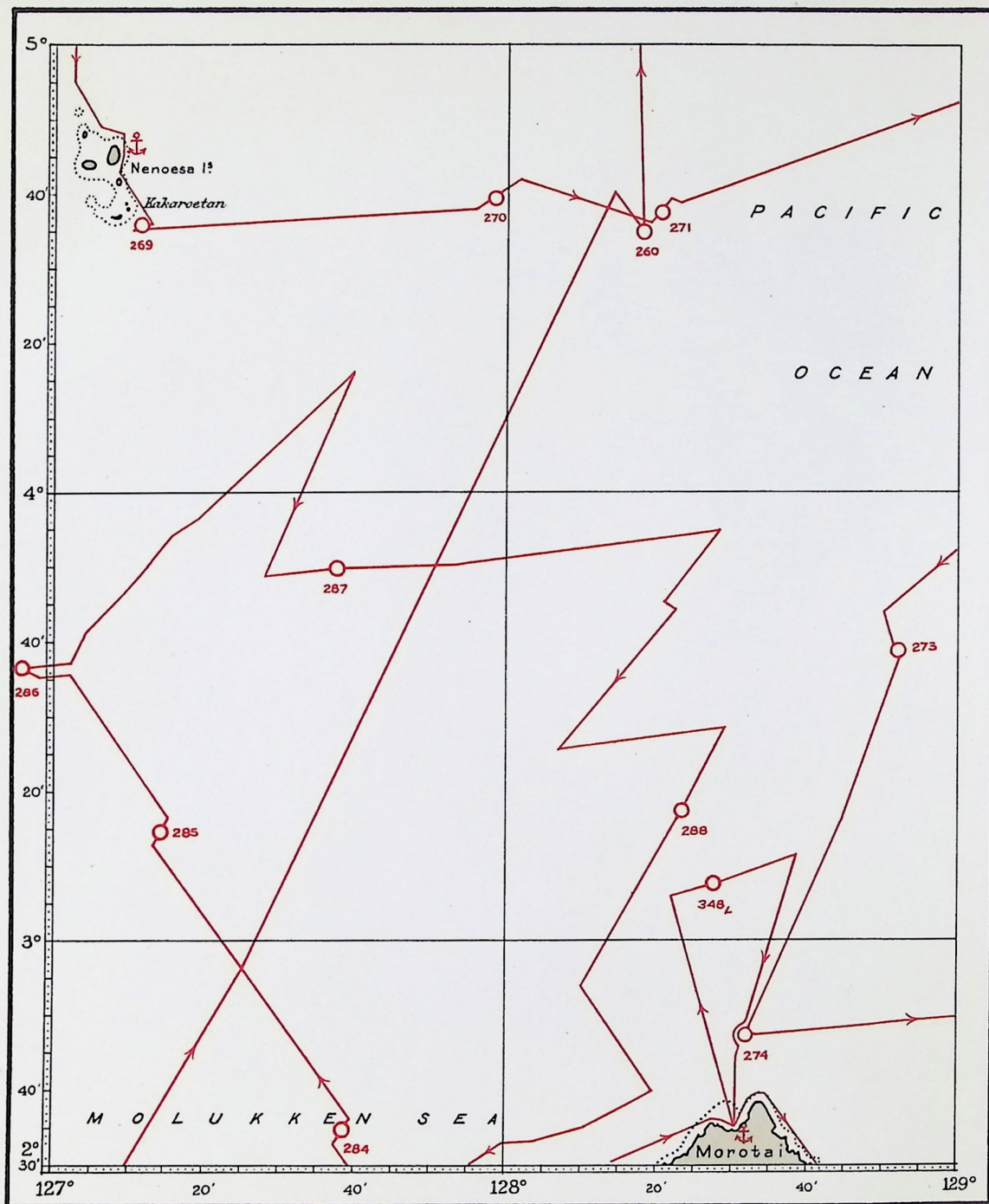


CHART 13. ENTRANCE TO THE MOLUKKEN SEA

10 0 10 20 30 40 50 60 70 80 90 km

Scale 1:1500000

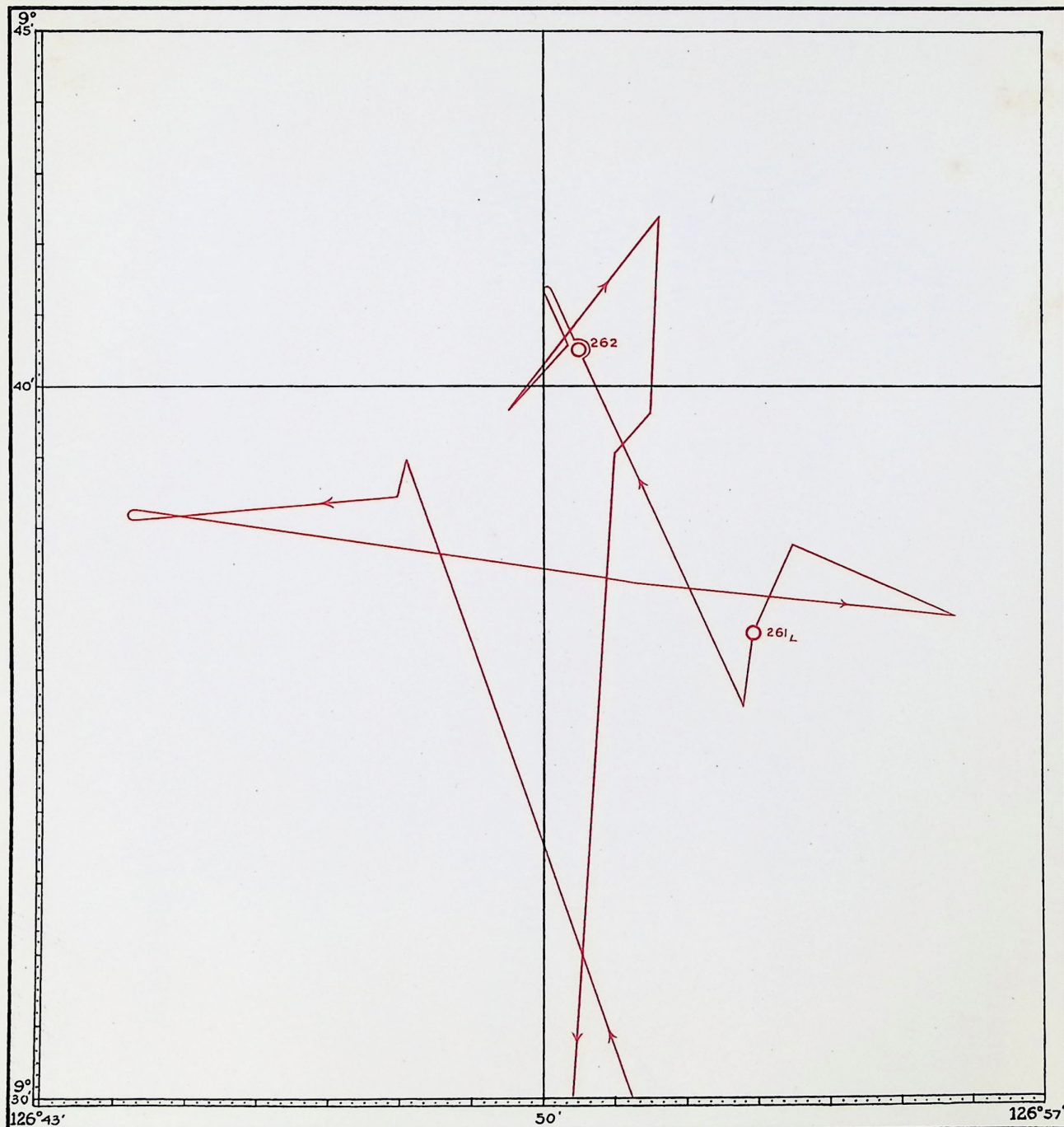


CHART 14. MINDANAO TROUGH

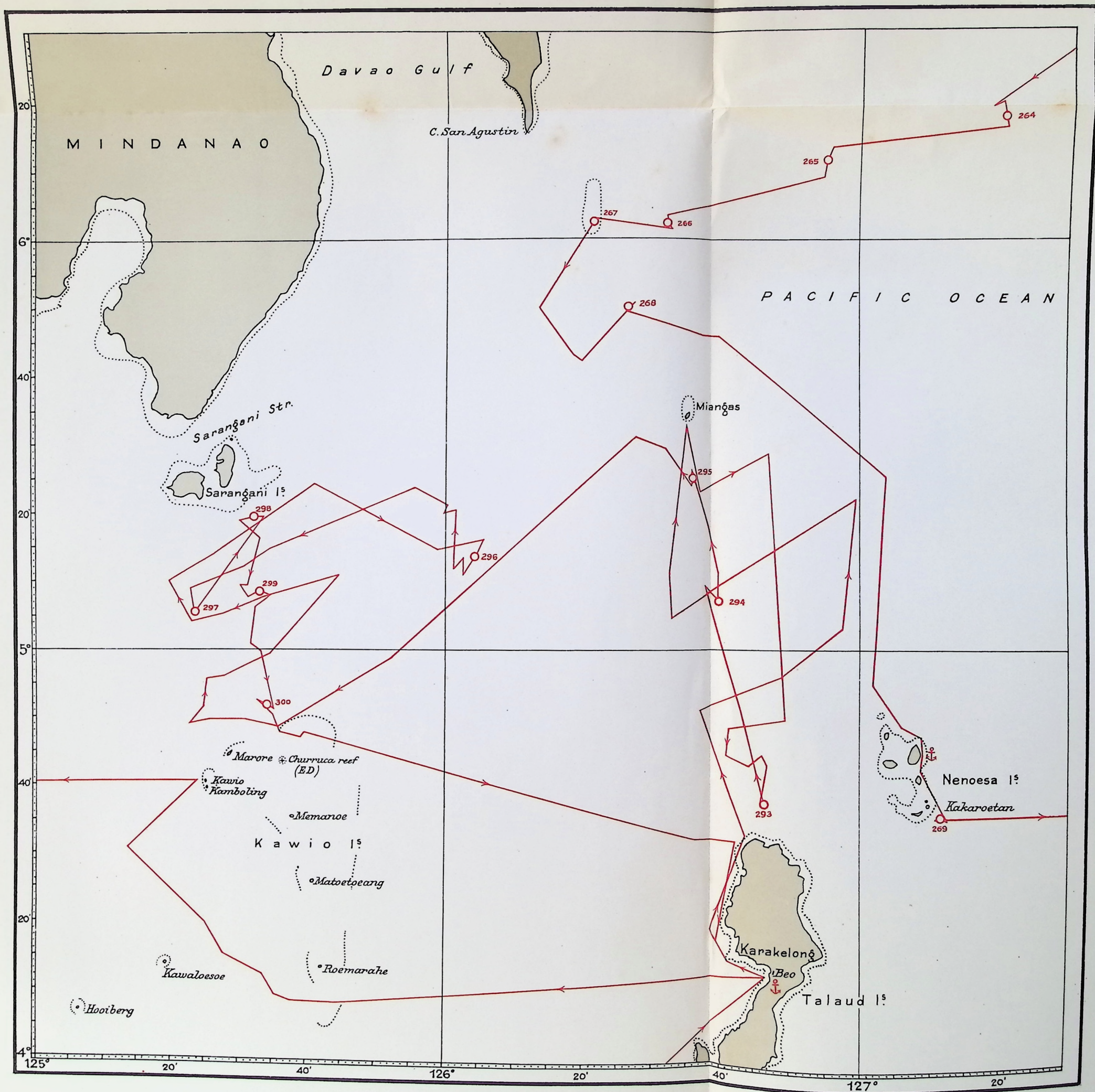


CHART 15. ENTRANCES TO THE CELEBES SEA

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Scale 1:1 000 000

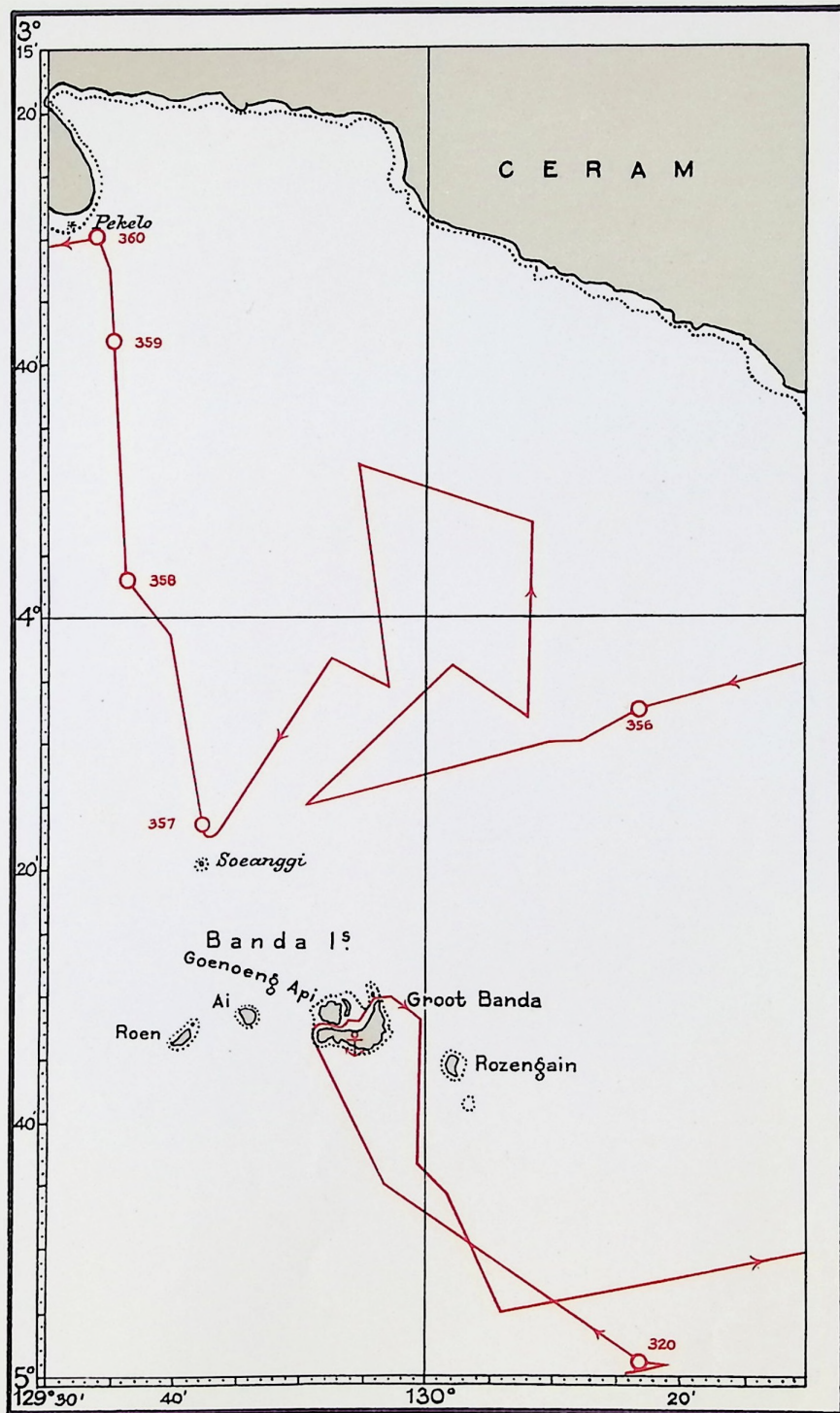


CHART 16. BANDA PLATEAU

10 0 10 20 30 40 50 km

Scale 1:1000 000

TRACK OF THE SNELLIUS-EXPEDITION IN THE EASTERN PART OF THE EAST INDIAN ARCHIPELAGO 1929-1930

SCALE 1:3.250.000

EXPLANATION

- Track of H.M.S. Willebrord Snellius
- Ordinary station
- Wine sounding station
- Zoological station
- Anchor station
- Anchorage
- Contour of depths of 200 m.
- Detail chart

PACIFIC OCEAN

